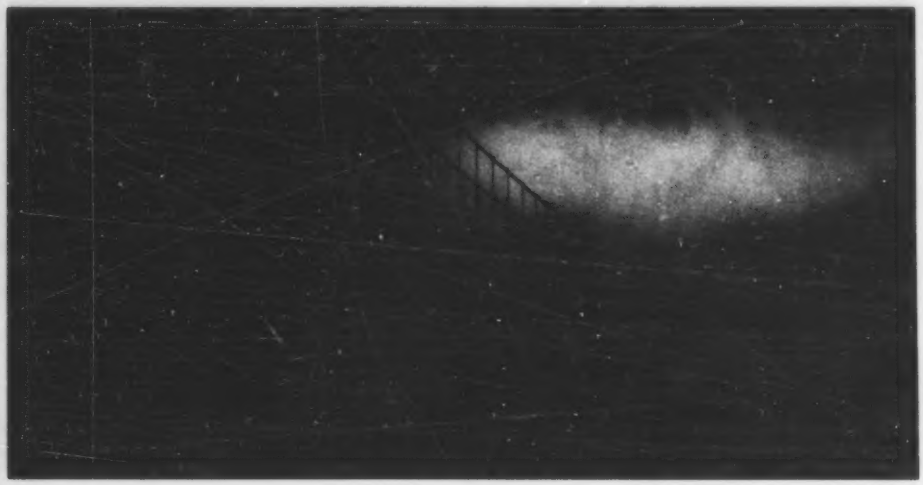
Building the Future

Issues in Public Infrastructure in Canada



Aidan R. Vining and
John Richards, editors

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Policy Study 34

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Foreword

The spread of humanity across the globe is indistinguishable in pattern from the spread of physical infrastructure. Where humans go, so eventually do walking trails, trade routes, highways, and communications networks. In turn, the distribution of infrastructure, whether embodied in ports, rail lines, or grain-handling facilities, steers the subsequent distribution of people and their economic activities.

Notwithstanding this feedback process, the emplacement of infrastructure is not the passive result of economic determinism; infrastructure investment follows from conscious decisionmaking. The welfare and economic health of a nation's population depends in part on the quality of decisionmaking, and that quality depends, in turn, on the information set and the analytical framework within which relevant information is considered.

This volume seeks to lay out, for the public policymaker as well as for interested observers, the key issues that enter into infrastructure decisionmaking. Part of the analysis rests on understanding public versus private roles in developing infrastructure, where the public role rests in filling in market gaps in infrastructure provision. A significant part of the decision requires determining the cost versus benefit of public investment in infrastructure; the presumptive good from correctly making that determination flows from sensible tradeoffs between present costs and future benefits. The chapters that follow are aimed at concise coverage of these issues.

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Jack M. Mintz
President and
Chief Executive Officer

The Study in Brief

Assessing the adequacy of infrastructure available to an economy is like assessing one's personal health: it becomes a subject of concern only when something goes wrong. The rest of the time, the temptation is strong to ignore the issue. Most Californians, for example, were oblivious to the impact of regulation and regulatory change on the availability and price of electrical power until a combination of political, market, and environmental events culminated in rotating blackouts, events usually associated with Third World countries. Similarly, residents of central Canada did not much concern themselves with the reliability of the power grid until the 1998 ice storm.

This collection of essays attempts the almost impossible: to interest policymakers in infrastructure policy, writ large, without the spur of an immediate crisis. The rationale is the belief that investments in certain *general purpose* assets are a necessary — if far from sufficient — condition for sustained economic development.

That said, we must acknowledge that there is no accepted definition of what comprises infrastructure. Few will dispute that it includes physical facilities such as roads, railroads, seaports, and airports. Most would extend the set to include basic utilities (electricity distribution and urban water systems) and the transmission facilities for electronic digitized communication (information technology hardware).

But we would argue that the list should be extended beyond physical investments to include intangible human capital. Emerging evidence suggests that investments in, for example, general purpose education and training are as important as investments in airports and highways. Indeed, the quality of a country's aggregate human capital, rather than its physical facilities and machinery, is probably the primary determinant of economic growth.

In the first essay in this volume, we provide a simple framework for thinking about government's role as either a provider or facilitator of infrastructure, differentiating among types of infra-

structure and the severity of market failures arising for each type. (Private markets in a sector are said to fail when key characteristics of the sector prevent approximately rational individual agents from generating an efficient outcome.) The more serious the market failures, the more extensive should be government intervention. To quote from our concluding paragraph:

> The main message is that infrastructure policy is important, but, unfortunately, it is complex and hard to get right. Different infrastructure investments in different sectors of the economy require different things from government. Some need public money, some need effective public management, and others need less public management and more accommodation of cost-minimizing and profit-maximizing market behavior.

In other words, the devil's in the detail. We take from David Gillen's essay the negative, but nonetheless important, policy conclusion that the supply in particular sectors may well be below or above optimum but the *aggregate* supply of Canadian infrastructure is probably adequate. Another of Gillen's conclusions is the importance of pricing, where feasible, as a means to reveal demand for infrastructure. Finally, in deciding whether to undertake particular public infrastructure projects, what should matter to decisionmakers are the results of evaluative techniques such as cost-benefit analysis.

Over the past generation, it has become normal for politicians, journalists, and the general public to pose questions about appropriate noninflationary monetary policy. We hope an analogous maturation takes place with respect to discussion of infrastructure policy. The general public should expect governments to report cost-benefit analysis results prior to launching major projects. Journalists and politicians should understand the logic of these techniques sufficiently to pose meaningful questions about net present values, discount rates and other such concepts.

The Current State of Canadian Infrastructure

David Swimmer undertakes a heroic exercise to compare the adequacy of contemporary Canadian infrastructure, relative to that of

other industrial countries and relative to Canada's infrastructure in previous decades.

He reviews the findings of a Swiss group, IMD, which concludes that, as of 1999, Canada failed to make the top ten ranked countries in seven of twelve measure of *basic infrastructure* and two of ten measures of *technological infrastructure*. Overall, IMD concludes, Canada's ranking slipped in the 1990s. World Economic Forum, another organization comparing infrastructure, is more optimistic, ranking Canada second in overall infrastructure in 1999. Such rankings are fraught with uncertainty, however, and Swimmer considers in some detail the stocks, and additions to stocks (that is, investment), in major infrastructure sectors. Gillen's cautions should be next in mind when evaluating the value of such league tables.

The nature of aggregate private and public infrastructure has changed since the 1960s. Four decades ago, the construction component (railbeds, highways, and so on) dominated; now, machinery and equipment does. Swimmer identifies two broad explanations for this change. One is the energy price shock post-1973, which provided an incentive for firms to invest in new energy-saving equipment. The second is the digital revolution.

Assessing the Evidence

David Gillen conducts a broad and rigorous survey of evidence on the links between public infrastructure investment and economic growth. He takes the reader through the range of theoretical approaches:

- *Aggregate production function studies*: Researchers using this approach posit an aggregate production function in which public infrastructure is one among several inputs required to generate an economy's output.
- *Cost function studies*: Here, researchers attempt to capture more about firms' optimizing strategies than is feasible via the production function approach. Cost function studies examine the extent to which public infrastructure (highways, for example) affect production costs and firms' input choices.

- *Endogenous growth theory*: Over the past two decades, researchers have measured the effects of particular variables as determinants of productivity growth. Some of these studies entail variation in infrastructure levels (such as the level of research and development).
- *General equilibrium models*: The most ambitious theoretical approach fits infrastructure into multi-equation models of a national or regional economy. This allows estimation, for example, of the opportunity costs elsewhere in an economy when revenues from taxes are diverted to public infrastructure investment.

The empirical results of these various approaches are far from consistent. After a thorough assessment of the evidence, Gillen is cautious about any moves to increase aggregate public infrastructure investment:

> [S]hould government change its policy to undertake once again more public capital investment in infrastructure? I say no. The most compelling argument is that such investment redistributes costs and benefits, rather than augments overall economic productivity.

Rather than concern themselves with aggregate infrastructure investment, decisionmakers should pay more attention to the amount and quality of infrastructure in particular sectors. They should also accord an increased role to pricing as a mechanism to reveal the demand for — and indicate the appropriate supply of — public infrastructure:

> [W]hat is required is an institutional change in the way public capital is funded and managed. The disconnect between user payments and investment has led to too much public capital in most cases and not enough in others.

The Social Discount Rate in Canada

Typically, infrastructure investments last a long time. They entail present costs and the prospect of future benefits. That benefits and

costs of infrastructure projects may accrue far in the future requires decisionmakers to think carefully about the problem of discounting the future in order to arrive at an equivalent to current costs and benefits. The social discount rate (SDR), an analogue to market interest rates, is the parameter defining the varying weights to place on project benefits and costs accruing in different time periods in order to arrive at present values. For a typical infrastructure project, in which costs precede benefits, an increase in the SDR will lower the present value of benefits more than the present value of costs. *Mutatis mutandis*, a decrease in the SDR will raise a project's net present value. Small changes in the SDR frequently change the sign of a project's net present value. Hence, the choice of the level of the SDR is a crucial parameter in the conduct of cost-benefit analysis.

Mark Moore, Anthony Boardman, and David Greenberg analyze the appropriate SDR for evaluating infrastructure projects in Canada. They focus on what they see as the three crucial issues: whether or not to use a market interest rate as a measure of the SDR; whether and how to account for a project's effects on future generations; and how to account for the impact on investment versus consumption.

The authors disagree with the Treasury Board's recommendation of a 10 percent real SDR, viewing it as too high. Next, they outline the hypothetical situation under which the choice of an SDR would be obvious, and show why, alas, the real world is far from meeting these requirements. They then outline and critique eight separate approaches to choosing an SDR: using some kind of market interest rate (methods 1–4); an approach based on an explicit societal valuation of the well-being of future generations (method 5); approaches that weight a project's impact on investment as a multiple of its impact on consumption (methods 6 and 7); and an approach with a variable SDR (method 8), one whose value declines as a project's time horizon lengthens, in order to allow serious present-day evaluation of very long-term environmental or health effects. Moore, Boardman, and Greenberg conclude with their best judgments about the discount weights to use in any given situation, and suggest upper and lower bounds.

Criteria for Infrastructure Investment

How should government decide whether any particular role in infrastructure investment is socially desirable? Cost-benefit analysis provides the starting point. A fuller normative framework, however, requires that attention be given to distributional impacts as well as to the economic efficiency impacts valued with cost-benefit analysis. Theoreticians have to recognize the harsh reality that any normative framework will be implemented by public officials who face political incentives that often conflict with normative prescriptions. A prudential approach attempts to create institutions that push, however gently, political choices in the direction of the appropriate normative values.

Aidan Vining and David Weimer here propose a prudential approach that requires federal departments, provinces, and local governments to conduct and make public cost-benefit and multigoal analyses of proposed infrastructure projects. This is along the lines of requirements of the US federal government and quite a few of the more sophisticated states. Over time, this innovation should improve infrastructure policies. Specifically, Vining and Weimer would require project sponsors to file studies with the Treasury Board and with the Public Accounts Committee of the House of Commons. The Treasury Board would post these studies on the Internet along with comments from interested parties. While no panacea, the process would tend to discourage excessive benefit claims, provide a way to generate information about costs and benefits from those affected, and contribute to a gradual improvement in the analytical capability of the units of government that play important roles in the design and choice of infrastructure projects.

The Information Superhighway

If one splits infrastructure into a number of broad categories, then the fastest-growing of these is transmission facilities for digitized information. Steven Globerman carefully assesses the potential role of government in this sector by examining the extent to which market failure takes place in it. Likely the most important market fail-

ure is network externalities — the idea that the social return from expanding access to the Internet exceeds the private return to firms and individuals considering such investments. This gap suggests that the level of investment in Internet infrastructure is too low. While, in principle, market failure warrants government policies to accelerate access, Globerman is cautious: "The available evidence does not permit persuasive argument about whether government is doing too much or too little subsidization." He is concerned that enthusiasm for the Internet is leading to "inefficiently large direct and indirect public sector investments."

Evaluating a Large-Scale Infrastructure Project

As Vining and Weimer demonstrate in this volume, cost-benefit analysis is an important tool for the evaluation of infrastructure investments. The principle underlying cost-benefit analysis is to evaluate project benefits in terms of what consumers would be willing to pay if the benefits were sold in a market, and to evaluate project costs in terms of benefits forgone due to the diversion of resources to the proposed project. The rationale for cost-benefit analysis is to subject decisionmaking on infrastructure projects to the discipline of a competitive market, if it were feasible to organize one. Unfortunately, cost-benefit analysis is only as good as its practitioners, who may bias results by an inappropriate choice of paramater values, and as the politicians in charge, who may simply ignore unwanted results.

Fernand Martin summarizes a particularly rigorous application of cost-benefit analysis: a joint undertaking of the Quebec, Ontario, and federal governments to evaluate a high-speed rail connection along the Quebec City to Windsor corridor. The study, completed in 1995, analyzed in detail six variants, differentiated by choice of technology (the Lynx technology used by the French high-speed rail system, TGV, or the less expensive but slower Sprintor technology) and route length (various routes along the entire corridor, or along the shorter Montreal-Toronto section of the corridor). Most variants generated a positive net present value using the base

values for the parameters. The most attractive, in terms of generating the largest net present value, was a variant using Lynx technology, between Montreal and Toronto, passing through Dorval airport, Ottawa-Hull, and Kingston.

Aidan R. Vining
and John Richards
April 2001

Thinking about Infrastructure

John Richards and
Aidan R. Vining

The rationale for studying infrastructure lies in the belief that investments in certain general purpose assets are a necessary — if far from sufficient — condition for sustained economic development. Most infrastructure is either publicly supplied, privately supplied with significant public subsidy, or privately supplied with close public regulation. The papers in this book explore various way of thinking about the many policy problems that arise.

Categorizing Infrastructure

One immediate problem is that no universally accepted definition of *infrastructure* exists. Neither is it always clear what circumstances justify its public provision, subsidization, or regulation.

The Composition of Infrastructure

Some analysts' definitions of infrastructure focus on the breadth of the physical sectors included. Few dispute that roads, railroads, seaports, and airports are infrastructure. Many also include other physical facilities, including basic utilities (electricity distribution and urban water systems) and the transmission facilities for elec-

Thanks are due to Finn Poschmann, Bill Robson, and David Weimer for helpful comments on earlier drafts.

tronic digitized communication (information technology hardware). An even broader view of physical infrastructure includes facilities for education and health care.[1]

An increasing number of commentators recognize, however, that an exclusive focus on physical infrastructure may still be too narrow, no matter how broad the scope of the facilities included (Schultz 1961; Becker 1964; Jorgenson and Fraumeni 1989; Laroche, Merette, and Ruggeri 1999). Investments in, for example, general purpose education and training may well be as important as investments in airports and highways. Indeed, human capital, rather than the capital embodied in physical facilities and machinery, may be the primary driver of economic growth (Lipsey 1996; Kirova and Lipsey 1998). Thus, in their contribution to this volume, Vining and Weimer argue for a definition of infrastructure as "the physical and human capital that broadly facilitates production, consumption, and further investment." With such a broad definition, the investment in basic research and development would also qualify as infrastructure (Griliches 1986).

Although a broad definition is almost certainly justified, it raises practical problems. Analysts usually find it easier to track the linkages between investment in physical infrastructure and any effects on the output of goods and services than the analogous linkages arising from investment in intangible infrastructure. As Gillen shows in this volume, even the former linkages are difficult to establish empirically. Moreover, in broadening the definition, the concept of capital investment itself becomes fuzzy. While K–12 schooling and postsecondary education are investments in citizens' income-generating potential, they are simultaneously consumption goods that directly improve students' quality of life.

In sum, extending the definition of infrastructure makes it harder to identify discrete infrastructure projects that can be evaluated incrementally and separately (Aschauer 1990).

1 This physical facilities approach to defining infrastructure includes such buildings but not operating expenditures on the salaries of teachers or health care workers.

Market Failure

In addition to listing the various kinds of assets that advance production, consumption, and further investment, we can usefully categorize infrastructure by the extent to which it is subject to *market failure*. (Private markets in a sector are said to fail when key characteristics of that sector prevent rational individual agents from generating an efficient outcome.)

Economists have long understood that agents in private markets face incentives to undersupply — relative to the amount required for optimum economic performance — goods that display "public good" characteristics. In addition, when profit-maximizing agents supply such goods privately, they may misprice. Government accordingly has a necessary role here: to regulate price and to assure adequate supply.

By definition, public goods display some combination of nonexcludability and nonrivalry. A *nonexcludable good* is one whose use cannot be cost-effectively denied to anyone desiring it. In such cases, a private firm usually cannot capture revenues sufficient to warrant economically efficient levels of supply. For example, consider highways. If toll booths are installed at all points of entry — an expensive but feasible option in certain cases — a highway can be rendered excludable: drivers who refuse the toll can be denied access. For most highways and for an urban road system, however, doing this is very costly. Nonexcludability means that most highways and urban roads are provided by government, are paid for via taxes, and are free at the time of use.[2]

The second defining characteristic of public goods is *nonrivalry* (the incremental cost of another user is close to zero). Many infrastructure projects display nonrivalry during certain times but not others. For example, passengers queuing for a bus at 7:30 in the morning render the bus system rivalrous because accommodating

2 That incremental use of a road is free does not preclude government from implementing pricing schemes that approximate marginal cost pricing. For example, a number of cities — most famously Singapore — use time-of-day road pricing. In order to reduce the social costs of road congestion at peak hours, the authorities require vehicle owners who wish to use the roads at such times to purchase permits to do so.

them requires the purchase of extra vehicles. On the other hand, passengers at off-peak periods, when buses are running with empty seats, are nonrivalrous; they impose no incremental cost on the system. The efficient strategy is, in general, to charge peak users the full capital cost and set capacity accordingly.[3] Simultaneously, it is efficient to charge much lower prices to off-peak customers, whose use generates low incremental costs and whose demand is usually not relevant to determining optimum capacity (Small, Winston, and Evans 1989; Winston 1991; Hau 1992; Anderson and Mohring 1997).[4]

In addition to public good characteristics, the supply of infrastructure may display other market failures that render an efficient outcome unlikely. One such failure is the presence of *natural monopoly* (where one supplier can realize significantly lower unit costs than several). Unregulated private suppliers in such sectors first tend to drive out competitors by setting low prices on the basis of scale economies; the successful survivor then pursues a strategy to maximize long-run monopoly returns. Under these circumstances, government regulation may be able to improve efficiency in pricing and to assure appropriate capacity.

A third market failure results from network externalities, which arise because the per capita benefit derived by users of a network — say, by speakers of a language or users of the Internet — increases with the aggregate number of users. By investing time and effort to learn a language or to gain access to the Internet, incremental users benefit not only themselves but also the network's established users, who henceforth can communicate with more people. Globerman (in this volume) explores the extent to which network externalities exist with respect to information technology hardware.

Markets are unlikely to supply infrastructure that displays pure public good characteristics (that is, close to complete nonri-

3 That is, to equate the cost of incremental infrastructure capacity to the willingness-to-pay of incremental peak customers.

4 Faced with time-sensitive demand, determining optimum capacity may require consideration of off-peak as well as peak demand. Optimum capacity depends on the price elasticity of consumer demand.

valry of consumption and nonexcludability). In other cases, less severe market failures may enable some, but not necessarily optimal, market supply. In infrastructure sectors displaying only moderate market failure, such as telecommunications, private firms have made enormous investments that may be close to optimal levels (Crandall 1997; Greenstein and Lizardo 1998).

An interesting example is e-mail, which has become a ubiquitous substitute for postal services. It has public good characteristics: obliging users to pay for individual messages with the equivalent of a postage stamp is not cost effective. Institutions are transforming e-mail into a public good for their workers by investing in the requisite software and Internet service providers. Other innovations have emerged. Private firms enable individuals with access to a computer and modem to undertake free e-mail communication. These firms supply e-mail as a public good by transforming it into a joint good: free e-mail service plus advertisements on their websites, paid for by advertising firms.

Classifying Infrastructure

The distinctions just made can be organized into the simple taxonomy of Figure 1. The horizontal axis distinguishes between physical and intangible infrastructure, while the vertical axis charts the severity of market failure. Each cell of the figure also lists illustrative examples. The public policy issues differ from cell to cell, but, in all cases, the quality of public governance is important in determining whether the potential benefits of public intervention are actually realized.

The following subsections elaborate a few aspects of infrastructure policy arising in each of the figure's cells.

Severe Market Failure / Physical Infrastructure

The situations in the severe market failure / physical infrastructure cell pose the problem of chronic lack of private supply. Infrastruc-

ture projects that simultaneously have public good and natural monopoly characteristics (for example, interprovincial highways, airports, and wharves) are likely to be both publicly financed and owned.[5] Assessing market willingness-to-pay in such circumstances is difficult.

In turn, public ownership raises the issue of encouraging efficiency-inducing governance. Maintaining the technical efficiency of publicly run operations is a continuing issue (Johnson and Libecap 1989; Frant 1993; Globerman and Vining 1996). Over the past decade or so, an important issue in Canadian public policy has been experimentation with alternate governance solutions for infrastructure.

For example, Ottawa has transferred the management of major seaports and airports to nonprofit corporations whose directors represent local interest groups. It is not clear that this governance mechanism is adequately encouraging either efficiency or accountability. The Vancouver Board of Trade, for example, has complained about the lack of explicit accountability in the current governance structure of the Vancouver airport (Constantineau 2001). Additionally, local interest groups tend to ignore costs or benefits that are borne outside the locality. Commentators outside Toronto have vocally criticized the announced intent to impose a tax on passengers going through Toronto's Pearson airport. This approach, critics argue, is an abuse of the natural monopoly arising from Toronto's hub status in the Canadian airline network (Simpson 2001). The federal Department of Transport is expected to introduce new legislation regarding airport governance in the near future (Constantineau 2001).

5 Some analysts would dispute the location of airports and seaports in the category of "severe market failure." In many circumstances, the market failure may better be described as moderate. The key analytic question is usually the locational reach of the natural monopoly "footprint." Some seaports and airports have only very local monopoly power. In practice, they compete against, or at least face contestability from, nearby facilities. For many cargo categories, for example, the port of Vancouver competes against Seattle and, indeed, San Francisco. And the ports of various countries have undergone transformation into regulated profit-maximizing entities (Gomez-Ibanez and Meyer 1993, 211–230).

Figure 1: *An Infrastructure Taxonomy*

	Physical Infrastructure	Intangible Infrastructure
Severe market failure	*Examples* • nonarterial urban and rural roads • urban sanitation • seaports and airports *Policy issues* • public supply versus tendering for private supply • evaluation of willingness-to-pay and determination of optimum supply • public sector governance (e.g., monitoring quality)	*Examples* • K–12 education • pure R&D *Policy issues* • extent of public support • measurement of productivity of alternate teaching methods • public sector governance (e.g., public sector salary determination, degree of budgetary devolution, role of charter schools and vouchers)
Moderate market failure	*Examples* • rail infrastructure • power utilities *Policy issues* • potential for privatization • design of efficient regulatory system • public sector governance (e.g., provincial versus federal responsibility, design of commercial Crown corporations)	*Examples* • applied R&D • postsecondary education *Policy issues* • assuring productivity of public supply • pricing (e.g., setting tuition fees) • public sector governance (e.g., degree of autonomy granted to universities and colleges)

To amplify, transforming these entities from line agencies of the federal government into nonprofit local organizations does not deal with the fundamental problem of generating strong responsiveness or accountability to users, who are the relevant principals. The rationale for the present strategy is that local interest groups, via representatives among the directors, will assure efficient management of their respective facilities. To continue with the example of Vancouver airport, its directors have only tenuous accountability to local airport users and none to the diffuse constituency of nonlocal users. The efficiency of nonprofit organizations is clearly a problem, especially for those with large, diffuse constituencies (Covington 1994).

Moderate Market Failure / Physical Infrastructure

The combination of moderate market failure and physical infrastructure raises intertwined issues: the potential for privatizing state-owned utilities, the design of regulatory regimes, and raw redistributive politics. Since market failures are less severe than in the first cell, the potential for market solutions is greater. When private firms supply infrastructure, public policymakers face a dilemma. They must choose a regulatory regime bearing in mind the inevitable tradeoff: aggressive regulation may avoid most market failure outcomes, but, in turn, may enable politically sanctioned inefficiencies worse than those eliminated (Gomez-Ibanez and Meyer 1993; Bowden and Klay 1996; Engel, Fischer, and Galetovic 1997).

The infrastructure involved here comprises assets whose services are needed for many sectors of the economy. This feature places a premium on stability of price and supply. When that stability is threatened, the political reaction can be swift and angry, as events in the California electrical market illustrated during the winter of 2000/01.

California reformers had attempted to improve efficiency by unbundling — that is, requiring established utilities to compete with new private producers in electrical production and restricting the former's monopoly to distribution. By requiring the utilities to buy power from private sources, the state introduced some competition at the production and wholesale levels — but also unexpected instability. Increases in consumption in recent years have been larger than predicted, and investments in generating capacity have proved inadequate.[6] Consequently, the volume of power pur-

6 Several factors, unexpected at the time deregulation was planned in the early 1990s, contributed to the market disequilibrium. Powering the Internet is one unexpected factor to have increased demand. The hot summer of 2000 induced both a jump in demand and reduction in available hydro-based power in the region. The complexity of California's regulatory approval process delayed investment in state-level capacity and forced utilities to import power, not only from out-of-state but also from Canada. See "California's Power Crisis: A State of Gloom." *The Economist*, January 20, 2001, pp. 55–57.

chased by California utilities has been large. In late 2000, spot electricity prices were six times higher than they had been a year earlier. California legislated to protect consumers by preventing the utilities from passing cost increases through to customers, and it thereby imposed huge losses on those firms, losses that endangered the sector's financial integrity. A price cap that forces even well-managed firms into bankruptcy makes no sense; on the other hand, public expectation of stability in the pricing of infrastructure services means that a successful regulatory regime must be able to moderate the rate of increase in price. In sum, the California reform was inadequately integrated with other state policies and lacked sufficient contingency planning (Jaccard 2001).

The power crisis in California illustrates the potholes along the road to reform. Nonetheless, well-designed price-cap and incentive regulation of private suppliers can bring about more efficiencies than traditional rate-of-return regulation. The latter requires regulators to estimate the costs of provision for each service and to establish a rate structure such that the firm realizes an acceptable, but not excessive, rate of return. This strategy imposes large information costs on the regulators, and affords the regulated firms limited incentives to improve efficiency. The former, price-cap regulation, requires firms to realize an average price of service below contractually specified levels over the life of the contract, which is usually several years.[7] In general, this regime lowers regulatory information costs and improves the efficiency of operations among regulated firms. Why? If firms realize efficiencies, they retain the incremental profit during the life of the contract (Mathios and Rogers 1989; Kaestner and Kahn 1990; Resende 2000).

Severe Market Failure / Intangible Infrastructure

The mixture of severe market failure and intangible infrastructure raises many of the same problems, such as lack of private supply, as

7 Subject to the overall cap, the firm has considerable freedom to determine individual prices of service.

does the analogous combination for physical infrastructure. But it also presents some unique issues, given the difficulties of evaluation.

Achieving near-universal literacy and basic numeracy are almost certainly prerequisites to sustained economic growth. Yet the market failures surrounding provision of K–12 education are so severe that no country has been able to achieve general literacy and numeracy among its citizens without resort to mandatory schooling, most of it publicly supplied. However important investment in this form of basic human capital, the evaluation of effectiveness of alternate teaching methods and of alternate school systems is difficult and often fraught with ideological *Sturm und Drang*. Consider two examples: the whole language versus phonetics debate over the optimal technique for teaching Ontario children to read, and the argument over preserving confessional schools in Quebec (see Ontario Coalition for Education Reform 1999; Caldwell 2000).[8]

Moreover, in judging the efficacy of investment in education and training, evaluators must assess the induced increase in earning potential. Frequently, the lag between the costs incurred and any benefits generated is a long one, and it is difficult to pin down the incremental effect of the education or training relative to the impact of other intervening variables (Pack and Pack 1993; Devarajan, Squire, and Suthiwart-Narueput 1997). Nonetheless, evidence exists that, in comparing the economic performance of countries, the level and quality of this intangible infrastructure matters a good deal (see, for example, Mansfield 1991; Mansfield and Lee 1996; Howitt 1996; Martin 1998; World Bank 1995).

Moderate Market Failure / Intangible Infrastructure

The combination of intangible infrastructure and moderate market failure, exemplified in applied R&D, postsecondary education, and

8 Caldwell (2000) argues for preserving confessional-based school systems. His argument does not essentially concern the case for religious instruction. He wants two systems to survive and compete, enabling greater parental choice among publicly funded school systems.

training, produces some interesting challenges.[9] In the case of postsecondary education and firm-specific training, individuals and firms often internalize enough of the benefits arising to undertake close to optimal levels of human capital investment without government intervention (Devarajan, Squire, and Suthiwart-Narueput 1997).[10]

College and university training occupies a middle ground between K–12 education, where market failure is severe, and firm-specific training, where it typically is not. Among the issues posed by infrastructure investments here is establishing the appropriate distribution of costs between, on the one hand, students directly receiving the education (and hence many of the subsequent benefits) and, on the other hand, governments. In Canada, the student contribution to tuition declined as a share of university costs from the 1970s to the mid-1980s; it has since risen to about one-third of instructional expenditures. Also to be decided is the form of government support: direct grants to postsecondary institutions, loans to students, or income-contingent loan programs (Finnie and Schwartz 1996; Chapman 1996).[11] Finally, postsecondary education raises important equity issues (Garcia-Penasola and Walde 2000), making public investment in it an issue that requires multigoal

9 In 1998, Canada's gross domestic expenditure on research and development was 1.6 percent of gross domestic product (GDP). This share compared with US investment of 2.7 percent (0.4 percent military and 2.3 percent nonmilitary) and an overall average of 2.2 percent (0.2 percent military and 2.0 percent nonmilitary) in countries of the Organisation for Economic Co-operation and Development (OECD 2000, tables 5, 6). Pure R&D can be considered a form of intangible infrastructure. It has public good characteristics: once supplied, maintaining excludability is hard. Predictably, all governments contribute to varying degrees in the undertaking of R&D.

10 Market failures may be more severe than we are suggesting in situations that involve non-incremental change, such as retraining to enable workers in eastern Europe shift from slow-changing state-owned firms to faster-changing private firms (Fitzenberger and Prey 2000).

11 Income-contingent loan programs finance students while enrolled in school. They agree to repay the loan via a surcharge on their income tax after graduation.

analysis, not only cost-benefit analysis (see Vining and Weimer, in this volume).[12]

Imposing Discipline on Government

If governments do the right thing in terms of investments in infrastructure, their intervention in the provision and regulation contribute substantially to an economy's aggregate productivity. For example, in reviewing US experience, Fisher reports: "Of the 15 studies reviewed, a positive effect of highway facilities or spending on economic development is reported in 10" (1997, 54).

Frequently, however, governments do not do the right thing. Major infrastructure projects almost always entail discretionary decisions, and vote-maximizing politicians have strong incentives to oblige politically important interest groups, whether or not these lobbies can make a reasonable claim that their pet projects will generate a positive net present value for the economy.

As writers in the public-choice tradition have long argued, the lobbying influence exerted for and against any particular public decision is usually unbalanced, due to the law of concentrated benefits, diffuse costs (Olson 1982). The beneficiaries of any proposed airport, highway, or wharf are likely to be few relative to the jurisdiction whose treasury will be called on to pay for the project. If those beneficiaries pay only inasmuch as they are taxpayers within that jurisdiction, they have good reason to invest in lobbying on behalf of the project. And so long as the project is to be financed from general government revenues, nonbeneficiaries, each facing a small fraction of the project cost, have insufficient motive to constitute an effective counterlobby.

Although public officials and politicians have great difficulty achieving analytic distance from infrastructure projects subject to interest-group lobbying, governments have evolved means to con-

12 The issue of tracking the link between investment in education and economic benefits by use of cost-benefit analysis is rarely straightforward. Establishing the magnitude of the link has proved empirically difficult (Garcia-Mila and McGuire 1992: Dalenberg and Partridge 1995; Fisher 1997).

tain the perverse effects arising from the law of concentrated benefits, diffuse costs. Probably the most important is the convention, dating back at least to Magna Carta of 1215, that government seek approval from representatives of those paying — in a democracy, approval from the elected legislature — the taxes required to finance government expenditures.

This convention is, of course, complicated in a federation such as Canada that distributes responsibility for infrastructure across two orders of government. Decentralization of infrastructure decisions may improve the quality of decisions inasmuch as provinces that are financing infrastructure via own-source revenues must impose per capita project costs on their residents that are higher than would be the case if Ottawa undertook the same project. When citizens face higher per capita costs, public debate over the benefits and costs of particular projects is likely to be more balanced than is the case for projects whose costs are diffused over taxpayers beyond the province. Conversely, provinces face an incentive to underinvest in projects, such as interprovincial highways, many of whose benefits accrue to individuals and firms beyond their own borders.

Another mechanism that — potentially — disciplines governments to do the right thing is cost-benefit analysis. The underlying principle is to evaluate a project's benefits in terms of what consumers would be willing to pay if those benefits were sold in a market and its costs in terms of benefits that must be forgone due to the diversion of resources to the project. In other words, cost-benefit analysis is an attempt to subject decisionmaking about infrastructure projects to the discipline of a competitive market were it feasible to organize one. Unfortunately, cost-benefit analysis is only as good as the politicians in charge, who may simply ignore unwanted results, and its practitioners, who may bias the results by an inappropriate choice of paramater values. A crucial parameter choice in many instances is the discount rate. Moore, Boardman, and Greenberg (in this volume) provide a survey of good accounting practice.

Cost-benefit analysis is not a panacea, even when done carefully and its results taken seriously. It can identify crucial dimensions of uncertainty and may define useful confidence intervals around

a project's net present value. *Ex ante*, significant uncertainty often persists as to whether the *ex post* benefits of a particular infrastructure project will exceed its costs. (For a case study in the rigorous application of cost-benefit analysis to a potential infrastructure project, see Martin in this volume.)

Conclusion

The purpose of this introductory paper has been to provide a framework for thinking about governments' role in infrastructure. The main message is that infrastructure policy is important, but, unfortunately, it is complex and hard to get right. Different infrastructure investments in different sectors of the economy require different things from government. Some need public money, some need effective public management, and others need less public management and more accommodation of cost-minimizing and profit-maximizing market behavior.

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The Current State of Canadian Infrastructure

David Swimmer

Infrastructure, both public and private, forms the backbone of the economic system. It allows output to be produced and transported to and from markets; knowledge and information to be exchanged; the educational, social, and health needs of the population to be attended to; and energy requirements and other basic needs to be met. A modern economy cannot function without a modern, adequate, and efficient infrastructure.

The literature is replete with studies of the effect of infrastructure on economic and productivity growth, including those by Aschauer (1987; 1989; 1991; and 1993), Morrison and Schwartz (1992), Holtz-Eakin and Lovely (1995), Holtz-Eakin and Schwartz (1995), Hulten and Schwab (1994), Greenstein and Spiller (1996), and Rauch (1994), to mention but a few. In Canada, work on the same subject has been conducted by Sakhnini and Delorme (1994) and by Wylie (1995). But these studies estimate and examine the benefits infrastructure can provide, such as contributions to productivity growth; there exists little if any work — outside that of Swimmer (1993) and McCracken (1993) — on the magnitude and adequacy of Canadian infrastructure.

In this paper, I try to fill that gap. I assess the quantity of Canadian infrastructure, by both type of infrastructure (construction or materials and equipment) and by industry. I consider Canada's position relative to other countries, and how and why infrastructure investment over the past few decades relates to national output.

The views expressed in this paper are those of the author and are not necessarily those of Industry Canada.

The Definition of Infrastructure

Infrastructure is traditionally described as the bricks, mortar, and pavement of a society. Traditional "core" infrastructure consists primarily of construction: buildings, mass transportation facilities, roads, railroad tracks, hydro and telephone poles and lines, sanitary systems, and so on. Much of the literature uses this definition when measuring the quantity of infrastructure in order to estimate its effects on other factors. But the nature of modern economies has necessitated an updating of this definition to reflect their complex and technological nature. This expanded definition includes not only construction but also the machinery and equipment (M&E) contained within or attached to the construction. Consider, for example, electricity, which is produced in buildings housing turbines powered by water, steam, or nuclear energy. But a power system's cost is significantly higher than the construction costs of those buildings. It also includes the cost of developing the turbines, installing the electronics in the control room, and the like. Our general infrastructure definition, therefore, should cover the M&E associated with any construction. Examples include communications satellites, broadcasting systems, microwave towers, baggage handling systems in mass transportation facilities, air traffic control systems in airports, and so on.

The infrastructure definition used here includes both the construction and M&E components of the following industries:[1]

- transportation, including air, water, railroad, truck, urban, interurban, and pipelines;
- storage, warehousing, and grain elevators;
- utilities, including electric power, gas distribution, water systems, and others;
- telecommunications carriers and broadcasters;
- schools (elementary, secondary, and postsecondary), museums, archives, hospitals, and health and social services; and
- government expenditures at all levels on buildings, roads, bridges, utilities, and so on.

1 Using the 1980 SIC classifications.

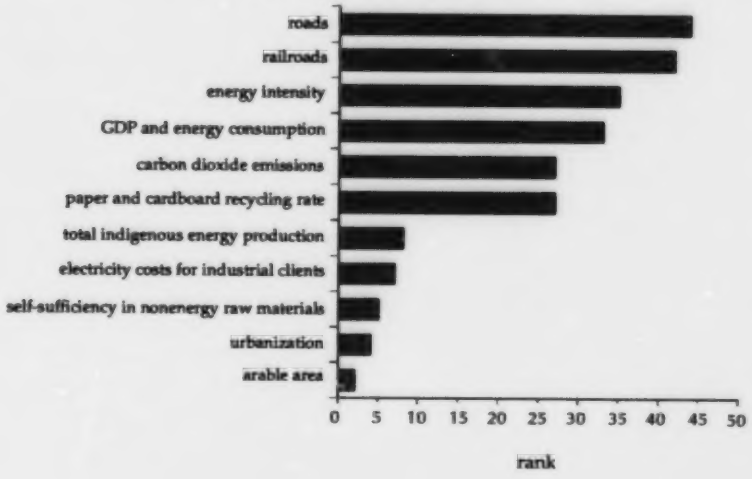
Canada's Infrastructure in a Global Context

The International Institute for Management Development (IMD), a Swiss group, is one of the few organizations that regularly examines the adequacy of infrastructure and makes comparisons among countries. Since it began producing intercountry comparisons some ten years ago in its *World Competitiveness Yearbook* (1998), Canada has ranked high on its list for infrastructure. Over the past few years, however, Canada's position has slipped. In 1999, Canada did not have a top ranking in any of the 22 infrastructure factors included in IMD's assessment. In fact, it was not even among the top ten countries in seven of the twelve "basic infrastructure" measures in which it had performed well in the past, or in two of the ten "technological infrastructure" factors. Canada's two lowest rankings in the "basic" group were for road and railroad density. These are not especially worrisome; since Canada's population is concentrated along the border with the United States, overall network density in the country is less important. Canada's highest rankings were in arable area and urbanization. These factors, in which the country ranked second and fourth in 1999, are not conventionally considered in measuring the adequacy of infrastructure. Canada did rank third in preparedness in dealing with the Year 2000 issue.

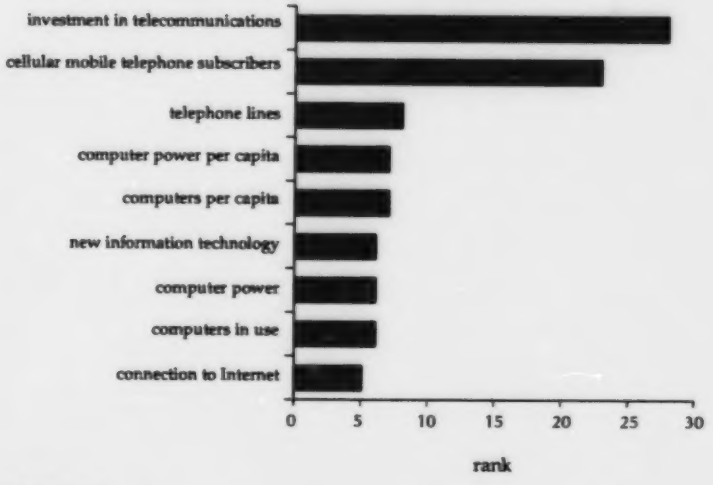
Let us look at Canada's rankings in terms of the industries listed in the last section (see Figure 1). In maintenance and development of infrastructure, Canada was ranked 15th. In transportation, including air, water, railroad, truck, urban, interurban, and pipeline transport, its rankings were poor, ranging from 7th to 44th. No data are available on where Canada stood in terms of storage, warehousing, or grain elevators. In utilities, including electric power, gas distribution, water systems, and others, its rankings were also low, from 7th to 15th, although the study lacks full information on these factors. Canada's position does not improve if one moves to telecommunications carriers and broadcasters, where its ranking ranges from 9th to 39th. As for schools, museums, archives, hospitals, and health and social services, the IMD report does not cover these factors. Nor does it have much to say about government expenditures on buildings, roads, utilities, and so on. A major conclusion that one can derive is that the basic infrastructure is not

Figure 1: *Canada's Global Rankings by Selected Infrastructure Indicators*

A: Technological Infrastructure



B: Technological Infrastructure



Source: IMD 1999.

being adequately measured by the surveys and statistics represented by the report.

Canada's performance is better in many technological infrastructure areas. It did well in some of the computer-based factors, such as computers per capita (6th), computer power per capita (6th), connections to the Internet (5th), and implementation of new information technology (6th). There are, however, two areas of serious concern. It ranked only 28th in terms of the ratio of investment in telecommunications to gross domestic product (GDP) and only 23rd in cellular phone penetration.

Another group, the World Economic Forum (WEF), found Canada to be performing somewhat better. In its listings, published in the *Global Competitiveness Report* (1999), Canada placed 2nd in overall infrastructure in 1999, 5th in railroads, and 3rd in air transport and ports. These factors are important because regularly scheduled maintenance can generate significant savings over the long run with regard to the construction component. The WEF also ranked Canada highly in power supply and in distribution and storage systems (2nd) but only 29th or 35th (depending on how it is measured) in investment in telecommunications and 12th in mobile telephone subscriptions. Canada is ranked 2nd among the Group-of-Seven (G-7) countries in information technology and 4th on the overall technology front.

These assessments are based partly on subjective survey data. An analysis of purely empirical evidence regarding Canada's technological infrastructure (IMD 1999) shows a more favorable picture. Among the G-7 countries,

- Canada uses automatic banking machines the most, averaging 45.9 transactions per capita in 1995, compared with 36.9 in the United States, 25.2 in the United Kingdom, and 3.8 in Japan.
- Canada's annual residential telephone charges were the lowest, its business charges second-lowest, and mobile charges second-lowest.
- Internet access charges were lowest in Canada, while Internet hosts per 1,000 inhabitants were highest.
- Home-computer penetration rates were highest and modem penetration was second-highest in Canada.

- Canada's number of telephone mainlines per 100 inhabitants was second-highest.
- Cable TV subscribers as a percentage of all TV households was highest in Canada, while TV receivers per 100 inhabitants was second-highest.

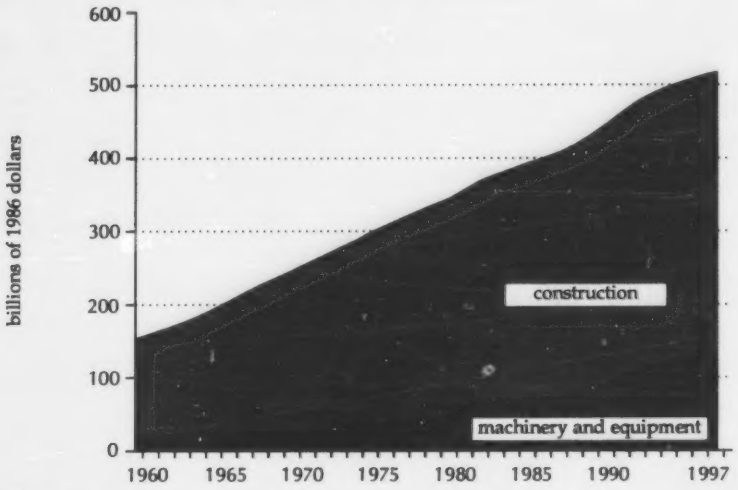
These facts, and the WEF results, indicate that Canada is likely doing comparatively well in terms of its technological infrastructure. However, to evaluate thoroughly the adequacy of the country's infrastructure, some common standards should be adopted.

Infrastructure Stock

What is the real state of infrastructure in Canada? Figure 2 shows infrastructure stocks and annual investment over almost four decades, from 1960 to 1997. Net infrastructure stocks (gross stocks less depreciation and discards) amounted to $516.8 billion in 1997,[2] comprising $136.8 billion in M&E and $380.0 billion in construction. Over the entire period, stocks grew at average annual rates of 3.3 percent — 5.36 percent for M&E and 2.79 percent for construction. Figure 3 shows, however, that this overall growth can be divided into two distinct periods, 1960 to 1975 and 1975 to 1997. During the earlier period, both components of infrastructure grew at an annual rate of 4.3 percent. The M&E part of the infrastructure stock averaged 11.4 percent of the total, a percentage that stayed relatively steady during those 15 years. From 1975 to 1997, however, M&E increased at an accelerated annual average rate of 5.8 percent, while the growth rate for construction fell to 1.4 percent. As a result, the M&E stock as a proportion of the total doubled from 12.4 percent in 1975 to 26.5 percent in 1997, while construction fell from 87.6 to 73.5 percent. Taken as a percentage of GDP, the stock of infrastructure, seen in Figure 4, remained much the same for four decades, but its annual fluctuations increased and it came to reflect a larger M&E component.

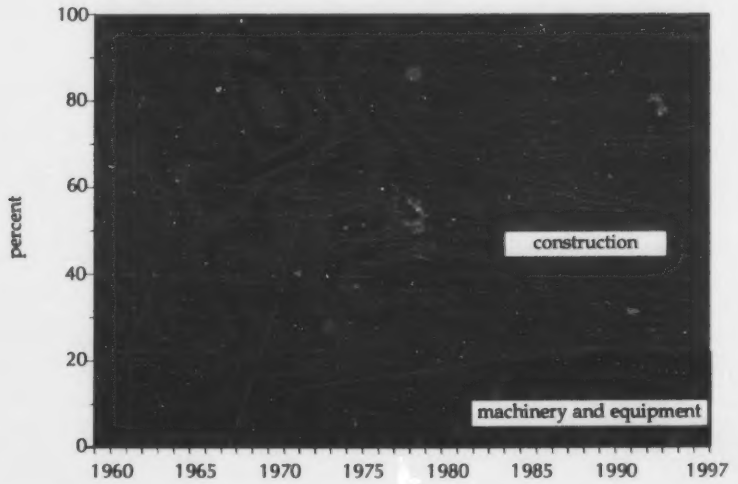
2 Calculated in real 1986 dollars, using the straight-line method of depreciation.

Figure 2: ***Quantity of Infrastructure by Type, 1960–97***



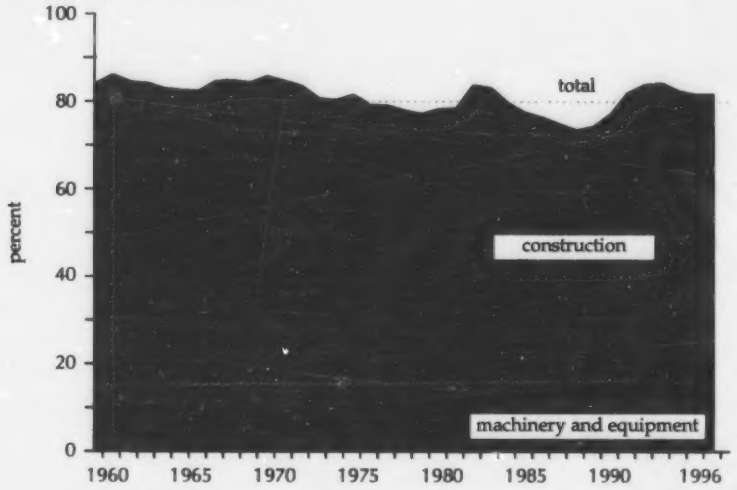
Source: Statistics Canada, CANSIM database.

Figure 3: ***Distribution of Infrastructure Components by Type, 1960–97***



Source: Statistics Canada, CANSIM database.

Figure 4: ***Infrastructure Stock by Type as a percent of GDP, 1960–96***

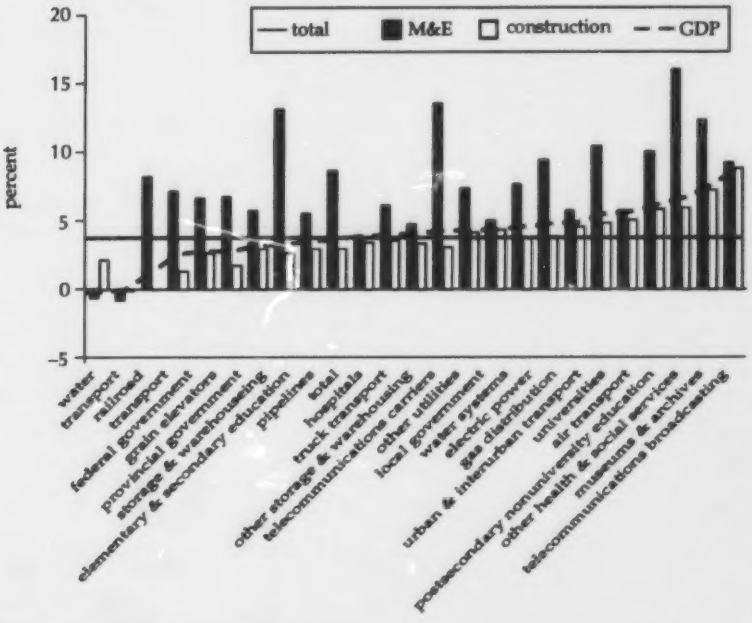


Source: Statistics Canada, CANSIM database.

Clearly, something happened to switch the emphasis in infrastructure investment from construction to M&E. One of the culprits was likely the oil crisis. Before 1973, energy was cheap, and there was little compelling reason to conserve or to replace energy-inefficient processes. After energy prices rose in the mid-1970s, one of the important conditions supporting sustained growth was investment in the installation and increased use of new technology that enabled energy savings. This kind of new technology is part of the M&E component of infrastructure. By 1975, Canada had started to replace old infrastructure technology with new, more modern M&E investment.

Figure 5 gives more detailed data for each type of investment in the infrastructure industries over the 1975–97 period. It shows that the annual growth of construction capital stock was below that of GDP in about two-thirds of the industries shown. Annual investment growth in M&E stock, on the other hand, was almost universally above GDP.

Figure 5: ***Average Annual Growth of Construction Infrastructure, by Type and Industry***



Source: Statistics Canada, CANSIM database.

The industry with the slowest-growing infrastructure capital stock (M&E plus construction) was water transport, which had an overall annual decline over the period of 0.3 percent. Its M&E component fell by 0.6 percent per year while its construction component grew by 2.1 percent. Fastest growing was telecommunications broadcasting, at 8.8 percent a year; M&E in the industry increased at 9.2 percent annually and construction rose by 8.8 percent. The order changes, however, when the criterion is growth in the M&E stock. In that scenario, railroad transport is the slowest growing, declining at an average rate of 0.8 percent. Construction stock also fell, by 0.1 percent a year. The fastest-growing average annual M&E stock was "other health and social services." Here, M&E increased by an average of 16.0 percent, and construction grew by 5.9 percent.

Is there a relationship between M&E growth and overall growth? The correlation between M&E capital stock growth and total growth has a coefficient of 0.398 — a weak relationship at best, but the sign is right. Are industries with the highest M&E stock growth rates significantly correlated with total growth rates? The correlation coefficient between the rankings in growth of total capital stock and its M&E component was a little higher at 0.498 — supporting the previous figure but still not significant.

Total infrastructure growth and M&E growth appear, therefore, to be unrelated. Part of the reason for this may lie in the age of the two types of capital stock. The construction stock component is older on average than M&E stock and can accommodate significant new M&E investment without itself needing to be increased. This is especially true in industries, such as telecommunications, in which the M&E stock is exchanged many times within the same buildings.

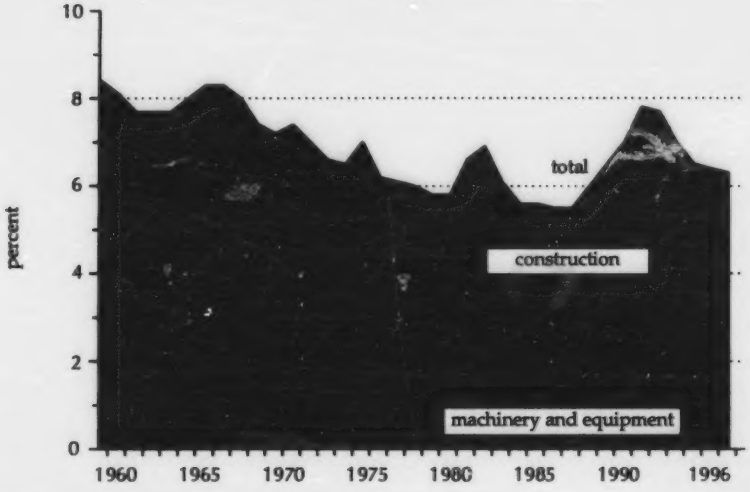
Annual Investment Flows

Annual infrastructure flows provide a clearer, dynamic picture (see Figure 6). While annual investment intensity (investment as a percentage of GDP) in infrastructure fell from 8.4 percent in 1960 to 6.3 percent in 1996, M&E overtook construction, rising from 1.0 percent of GDP in the early 1960s to 3.3 percent in 1996. Construction, on the other hand fell from 7.2 percent in 1960 to 3.0 percent in 1996.

A comparison of the first decade of the period under review (1960–69) to the last decade (1988–97) shows that the largest growth was again in telecommunications broadcasting, in which the difference was more than 1,200 percent (see Figure 7). Slowest was railroad transport, which declined by 33.9 percent between the periods. (To put those figures in perspective, all industries averaged only 133.3 percent.)

From the first ten-year period to the last, real average M&E investment grew by a low of 14.8 percent in railroad transport to an incredible high of 10,376.3 percent in other utilities (Figure 8). Overall investment was up by 580.3 percent. These large increases reflect two phenomena. First, investment in some fledgling indus-

Figure 6: ***Annual Infrastructre Investment as a percent of GDP, by Type, 1960–96***



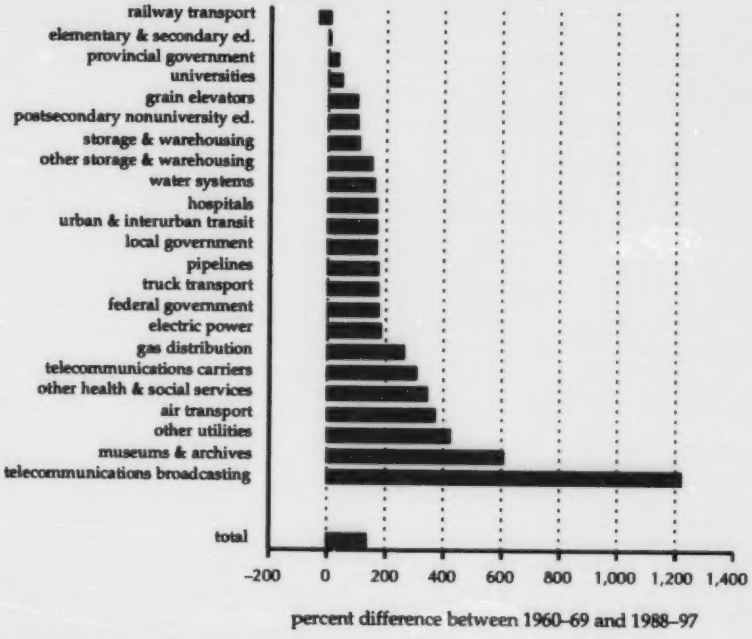
Source: Statistics Canada, CANSIM database.

tries, such as "other health and social services" and "other utilities," was very low in the 1960s; this fact exaggerated the relative growth rates. The second is a significant increase in M&E infrastructure spending in almost all industries. In fact, the lowest-growth industry experienced more than 100 percent growth. Even disregarding the two highest-growth industries, the overall first-last ten-year comparisons still averaged 571.6 percent. Clearly, growth was primarily in the M&E component of infrastructure.

Employment in Infrastructure

In 1997, more than a million Canadians were employed in the transportation, storage, communication, and utility industries. This amounted to 7.4 percent of total employment in the country, a figure that places infrastructure between the education and health-services industries. Interestingly, employees in both of these industries could also justifiably be counted as infrastructure employees.

Figure 7: ***Difference in Total Infrastructure Investment, 1960–69 and 1988–97***



Source: Statistics Canada, CANSIM database.

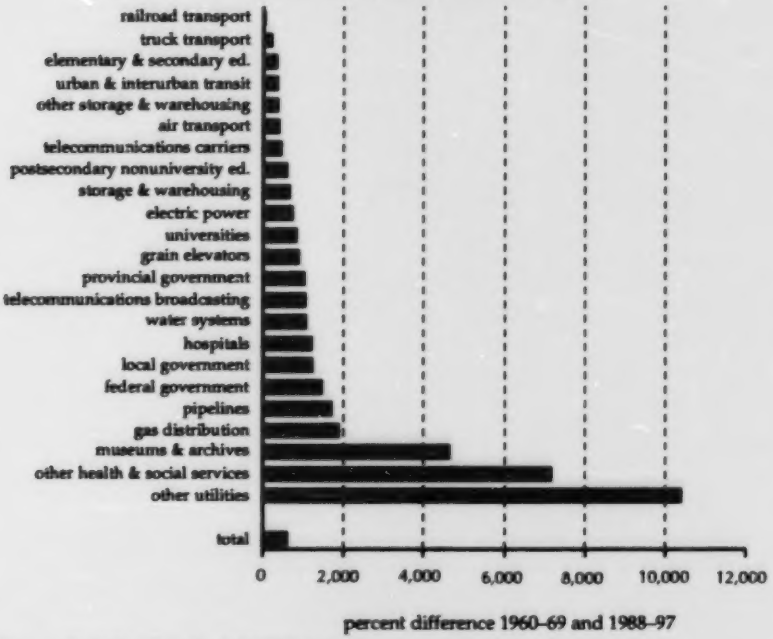
If they were, the infrastructure employment figure would rise to 3.4 million, or almost 25 percent of total employment.

From 1985 to 1997, infrastructure employment growth was 13 percent, situating it between retail trade (12 percent) and logging and forestry (15 percent). To put these figures in perspective, the highest growth was in community, business, and personal services, which grew by about 40 percent, and the lowest was in agriculture, in which employment declined by about 12 percent.

Capital Productivity and Misallocations

Most infrastructure is provided by government or quasi-governmental organizations, for the most part in industries in which there

Figure 8: ***Difference in Machinery and Equipment Infrastructure Investment, 1960–69 and 1988–97***

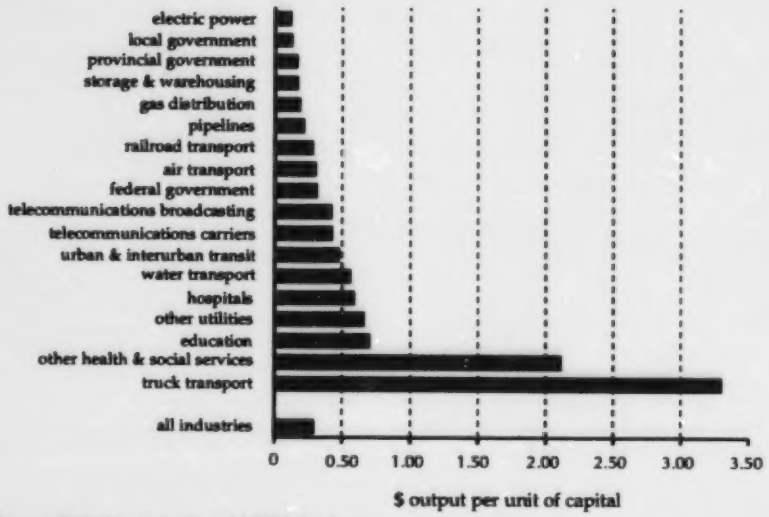


Source: Statistics Canada, CANSIM database.

is little if any profit. There are exceptions, but even these are regulated in some ways to moderate potential monopoly-like behavior. Capital productivity for most kinds of infrastructure is, therefore, expected to be smaller than in for-profit industries. The data bear this out; the highest infrastructure capital productivity is found in truck transport and nonhospital health and social services, both for-profit industries, and the lowest in various kinds of utilities, government, and public transportation all nonprofit industries (see Figure 9). Nevertheless, investment in the infrastructure industries should still follow the normal allocation criteria: invest where the productivity, benefits, or returns — in terms of profit or in terms of the public good — are highest.

How has infrastructure investment been carried out in Canada? Has capital been appropriately allocated in the infrastructure

Figure 9: ***Capital Productivity of Infrastructure Investment, 1996***

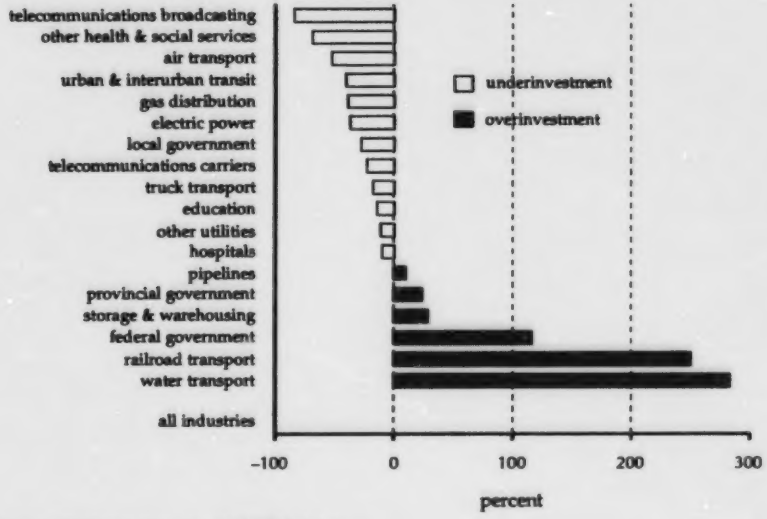


Source: Statistics Canada, CANSIM database.

industries? For the 1961–96 period, shift share analysis (recalculating 1996 infrastructure output according to the 1961 distribution, then applying 1996 capital productivity rates to the redistributed capital stock) shows little overall capital misallocation (see Figure 10). In fact, 1996 output would have been up by only 0.5 percent with the different distribution. But there are some significant differences among industries. For example, federal and provincial governments, pipelines, storage and warehousing, and rail and water transport all show evidence of significant relative overinvestment. Other industries, including many that are knowledge intensive, such as telecommunications broadcasting, health and social services, electric power, and telecommunications carriers, show evidence of relative underinvestment.

These misallocations of infrastructure capital may have contributed to the overall slowdown in the 1980s and 1990s of both labor and total factor productivity — and to Canada's infrastructure rankings as discussed above. When considering public infrastucture however, there may be little choice but to proceed with

Figure 10: ***Misallocations in Infrastructure Investment, 1961–96***



Source: Statistics Canada, CANSIM database.

some types of construction to provide the service rather than not to provide the service at all.

Conclusions

The first lesson to be learned from this study is how little has been written about the size and adequacy of the stock of infrastructure, in Canada or even worldwide, especially considering its acknowledged contribution to productivity growth. Various authors have estimated this contribution to be in the area of 20 to 25 percent.

A corollary to this conclusion is the importance of the changing nature of infrastructure. It does not consist solely of bricks and mortar, and it is becoming more knowledge-intensive. An expanded definition of infrastructure and measuring criteria that can account for its growing M&E content should be applied.

Second, according to outside estimates, the quality of basic infrastructure in Canada has deteriorated over the past decade or

so, pushing the country out of the top of the list of leaders in infrastructure supply. The good news is that harder data suggest that these statistics, which are mostly based on surveys, may not be as accurate as presented, and that Canada might be leading or close to it in the application of most aspects of infrastructure, especially technological infrastructure.

Third, the nature of infrastructure stock has undergone a fundamental shift, from primarily construction to primarily M&E. While annual overall infrastructure investment is down, more expenditure has gone into M&E, which is the "right" type of investment that embodies new technology. A more sophisticated infrastructure should be more able to align itself with future demands, especially from the viewpoint of information and its production and dissemination. The global economy is increasingly dependent on information and the ability to acquire accurate and relevant information quickly for informed decisionmaking.

Fourth, employment in the infrastructure industries ought not be overlooked. The changing nature of infrastructure itself means that skills level have increased. Infrastructure may now even be considered a knowledge-intensive industry.

Fifth, capital misallocations over the past few decades likely reduced the overall effectiveness of Canadian infrastructure. More analysis should be undertaken to determine the extent and remedy.

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Public Capital, Productivity, and the Linkages to the Economy: *Transportation Infrastructure*

David Gillen

Canada's economic history reflects a long-standing confidence in the links between transportation infrastructure investment and economic growth. In the nineteenth and twentieth centuries, a number of such investments were championed as generators of economic growth and development, projects that included the Canadian Pacific Railway, the Trans-Canada highway, and the St. Lawrence Seaway, as well as the country's major airports and airways system.[1] Until the 1970s, the conviction among politicians and policymakers was that building transportation infrastructure was a precursor to rising real incomes. This belief also applied to other public expenditure — including education, research and development (R&D), and industrial development grants.

True, over the 1920s and 1930s the country seemed to think that perhaps it had enough, if not too much, public infrastructure. This view stemmed in large part from the amalgamation of the second and third transcontinental railways into publicly held Canadian National, a union whose cost the taxpayers bore. In the 1950s and 1960s, however, postwar growth and urban expansion prompted rapid growth in roadways, airports, and water and sewer infrastructure that continued until the 1970s, when commentators and the public began to emphasize the social costs associated with transportation infrastructure: pollution, congestion, and accidents.

1 Until the mid-1990s, the federal government owned and operated all of Canada's sizable airports and most of its small regional ones.

The past ten years have seen renewed interest in transportation and related infrastructure investments and their link to economic growth. This resurgence followed the observed decline in productivity growth in the United States, Canada, and elsewhere, a decline that many date from the crisis of the early 1970s' oil price shocks.

One of the first analysts to investigate the role of public capital in both explaining the productivity slowdown and providing a potential solution was David Aschauer (1989c). Using national cross-section and US time series data, he reports a high correlation between lower growth in productivity and lack of public infrastructure spending.[2] Aschauer argues that public infrastructure ought to be included as one of the inputs into private sector output. His findings imply a return to public capital investment frequently much exceeding that to private capital.

This view contrasts with many of the policy recommendations proposed elsewhere. For example, the Royal Commission on National Passenger Transportation (Canada 1993) recommends against any large public investment in infrastructure. It finds no convincing evidence of how such investment would lead to long-term economic growth and development. So its recommendation is to focus policy on getting infrastructure pricing right. In another study, Gillen (1998) sees no need to increase investment in infrastructure capital and probably no slowdown in investment in pub-

2 The debate on the declining performance of Canada's productivity growth, particularly relative to the United States, has yielded almost no consensus on whether there is a productivity problem and, if so, what the likely causes are. Statistics Canada challenges the existence of a problem, takes issue with measurement, and opposes figures released by the Organisation for Economic Co-operation and Development that claim Canada's productivity declined by 0.4 percent per year between 1980 and 1990 and again between 1990 and 1996. In its own report, Statistics Canada says that business sector productivity climbed by 0.5 percent annually in the 1980s and 0.7 percent in the 1990s. The agency expresses serious concern about comparisons of productivity levels across countries, even within the same industry, and opts for comparing growth rates in productivity. As for causes for the slowdown, if there are any, explanations include (in no particular order) high taxes, poor management practices, a declining dollar, an exodus of high-technology workers, declining commodity prices, free trade, high interest rates, and small firms.

lic capital (although the aggregate amount of public capital may be right, it needs reallocation to match demand with supply).

The recent determination of the Canadian and US federal governments to "build infrastructure"[3] seems to take thinking on the role of transportation and other public capital in the economy back 30 years to the belief that such investment can stimulate economic growth, solve problems in other industries, and provide countries with a competitive advantage. What is not clear is how these improvements are to happen. What is the linkage between public capital and economic growth and productivity? Is the gain to come through better management of infrastructure or through having more of it? How does public capital relate to other inputs, such as labor and private capital? Finally, what are the spatial consequences of infrastructure investment?

In this paper, I examine the relationship between public capital (with an emphasis on transportation infrastructure) and its impact on the economy. The essay is organized around three questions: what is the role of public capital? how do economists view this role? what infrastructure policy should government pursue? The following section looks initially at the relationship between transportation and the economy and then reviews the literature on the return to public capital, particularly highway capital, and the relationship of public capital to other inputs. The next section examines the relationship between transportation and economic growth; I review the basic endogenous growth model, contrast it with the more traditional framework, and then discuss the newer cross-sectional economic growth literature and what it implies about infrastructure investment. The final section summarizes, and discusses the possible policy implications of this literature.

Public Growth and Competitiveness

Should government change policy with regard to infrastructure investment? Ideally, the answer depends on the nature and extent

3 On June 9, 1998. President Clinton signed into law the *Transportation Equity Act*. Of the $203 billion in it, $167 billion is allocated to highway construction.

of any links between public capital investments, productivity, and, ultimately, economic growth. Thus, the question raises a number of problems: how to measure public capital, what categories of it to include, and how to compare seemingly disparate types (such as highways and educational expenditures). An even more fundamental problem is to decide exactly how public capital affects regional and national income — in other words, to decide the means whereby public investments lead to increased output.

The Measurement of Public Capital

Measuring public capital raises several issues. The biggest is how broad a net to cast. Few people would argue against the inclusion of roads, sewers, and water systems, but should one also include schools, hospitals, and other public institutions? The choice is not straightforward.

Beyond the breadth of the net are a number of measurement issues relating to the preparation of suitable and disaggregated public accounts. Unfortunately, present government accounting conventions are generally weak on these matters and do not report what analysts need to know.

First, public accounts typically do not distinguish net additions to public capital stock from replacements to the existing stock of assets. What is recorded are a department's total annual expenditures without separate categories for the resources used to rehabilitate old infrastructure and those spent to build new. The total expenditures are taken as the stock of public capital.[4]

Second, the accounts rarely if ever separate "primary" or "core" public capital — roads, sewers, and water supply — from "other," although most analysts believe that any potential link between public capital and economic growth involves the former. The point is to focus on the type of capital where its separate influence can be measured. While any link between "other" public capital and growth is less clear, ultimately that link is an empirical

4 If the capital is spatially distributed, knowing the size of the network is important in evaluating its contribution to economic growth.

question. Therefore, the accountants should measure that "other" public capital in some way.

Third and ideally, the accountants should report the utilization rate of the capital stock. Most public capital is "lumpy," meaning the investments must be made in large, fixed amounts. However, the benefits of those investments depend on the actual *flow of services* from them. Therefore, capacity utilization is a relevant issue. Studies of private sector industry productivity now measure utilization. The same should be true of public sector analysis. In roadway studies, for example, the volume-to-capacity ratio would be a good measure.

Fourth, again ideally, one should account for different vintages of capital. Most public capital is long-lived and, if investment takes place at a fairly uniform rate, the distribution of vintages should be fairly uniform. But large differences are likely in the nature and features of the new and the old vintages. It is important, therefore, to consider some indicator of change in the technology embodied in public capital of different vintages.

Infrastructure and Aggregate Output

To understand the role of public infrastructure, one must first integrate it into a model of the economy, which may be at the macro (national) level, the regional or provincial level, or the industry or firm level.

The Macroeconomic View

At best, macroeconomic models can provide broad strategic guidance for managing the economy. For example, they may show the implications of shifts between public expenditure on social transfer programs and on real capital investments. But such implications remain uncertain; even if a model shows public infrastructure contributing, on average, to economic growth, one cannot automatically say that further investment is desirable.

Moreover, macroeconomic models give no direction as to what type of infrastructure capital is desirable. Making such decisions

requires microeconomic project evaluation (for example, cost-benefit analysis). Those points made, it remains true that an ability to better measure the overall or average effect of public infrastructure investments on economic growth would be a useful policy tool for considering expenditure priorities and budget allocations (Oum and Waters 1999).

The Provincial or Regional Perspective

At a lower level, one can view public capital as an input into a provincial or regional production function. In combination with private capital and other resources, such as labor, it generates regional output, income, and employment. In a regional context, public capital has direct effects on aggregate output by generating income and jobs. But public capital is also a factor of production in a firm's production and distribution process, a factor in almost perfectly elastic supply. The firm can alter how much it uses, but the amount it pays for use often bears little relation to the cost of provision. In many cases, infrastructure is free at the point of use — in other words, it is underpriced.

The impact of public capital is also felt through its relationship with other factors of production. It can complement or substitute for private capital, labor, and other private inputs. Government may simply be using public investment to substitute for private investment with an impact on the economy that is negligible or even negative. Public capital must be paid for with revenues raised through taxation; the cost of tax dollars may lead to a net reduction in the economy's output. The impact on employment, in the short term, may be positive or negative depending on whether the capital is a complement or substitute to labor.[5]

Public Capital as an Enabler

Some analysts say that public infrastructure has a facilitating role. It allows existing firms not only to do better what they do now but

5 In the long run, the impact of public capital will be felt through wage rates rather than employment.

also to do new things. Garrison (1994) argues that transportation investment stimulates companion innovation in nontransport sectors, leading in turn, to social and economic advances. The thesis is that transportation serves as an enabler for growth and productivity by creating opportunities to do things better by improvement or wholesale change; just as important is the opportunity to do different things. The slowdown in productivity growth may well be explained, therefore, by the notion that the companion innovations resulting from transportation have borne their fruit and cannot contribute further.[6]

In a study of the linkages between transportation investments and economic output, Garrison and Gillen (1998) make the point that US industry has been undergoing significant change in the use of transportation services and logistics operations since 1980. These reforms have arisen from policy changes (such as deregulation), shifts in the use of modes (such as moving from rail to truck), and infrastructure congestion. Just-in-time manufacturing strategies, for example, require partnerships that are highly reliant on transportation links. Improvement in highway infrastructure has enabled the significant improvement in truck transportation without which these partnerships would not have been feasible. Firms can respond in a number of ways to changes in the transportation system: with changes in product mix, in production techniques, in relationships with suppliers and customers, in locations for different tasks within the firm (scheduling, inventories, and so on), and in scale of operation. The indirect productivity improvements can be substantial as they accumulate over time.

Another view on this enabling role is that public infrastructure capital may act as a magnet or catalyst. The old designation of *social overhead capital* was based on the view that once (transportation) infrastructure is in place, it attracts economic development and growth in the relevant region and thereby diverts investment from other regions. Given that much public capital is underpriced, private firms gain an economic rent from its use.

6 This view is akin to the argument that certain industries reach a mature phase in which further productivity growth inevitably slows.

The Impact of Infrastructure: A Literature Review

The idea that public capital functions as social overhead capital has a long history in the economic development literature. Analysts have long perceived public roadways, ports, and water systems as prerequisites to economic growth and development. Much of this work is highly qualitative, anecdotal, or, like Solow (1956), couched in terms of traditional aggregate growth models.

The more recent literature is quantitative, ranging from estimates of macro economy-wide growth functions to industry-wide production or cost functions. The framework for analysis varies from time-series models of the national economy to models based on panel data disaggregated to the level of municipalities, counties, or states and provinces.[7] Most studies have used production functions or cost functions.

The Production-Function Approach

The production-function literature examining the effect of public infrastructure capital on output growth and productivity is wide ranging. These studies can be grouped into two broad categories: national level studies and regional or state level studies. (Table 1 summarizes a number of them.)

Aschauer (1989a) stimulates an extensive examination of the nature and magnitude of the impact of infrastructure capital on output and productivity growth in the United States employing aggregate time-series data to investigate the relationship between public investment and economic growth, estimates a production function relating the real aggregate output of the private sector to nonmilitary public capital. His finding is that infrastructure capital financed by the public sector increases the productive capacity of the private sector and stimulates investment there by enhancing the rate of return to that investment. Munnell (1990a) extends this

7 A panel is a data set that contains both cross-sectional and intertemporal observations.

Table 1: ***Selected Production-Function Studies***

Author	Specification of Functional Form	Data	Elasticity[a]	Comments
Aschauer (1989c)	Cobb-Douglas production function and TFP regressions[b]	time series 1949–85, private business economy	0.39–0.36 0.37–0.41 significant	CRS in all inputs,[c] including public capital
Munnell (1990a)	Cobb-Douglas production function, reproduces Aschauer	time series 1948–87, private nonfarm sector	0.34–0.41 significant	CRS in all inputs;[c] also private and public capital coefficient equal
Munnell (1990b)	Cobb-Douglas production function	cross-section, time series, 48 states, 1970–86	0.15	see Munnell (1991)
Munnell (1991)	Cobb-Douglas production function	cross-section, average, 1970–86; states values: 12 high endowment; 26 mid-endowment; 10 low endowment[d]	0.14 0.11 0.22 significant	returns to scale 1.01 1.03 1.04
Garcia-Mila and McGuire (1992)	Cobb-Douglas production function	cross-section, time series, 14 annual observations of 48 states; gross state production of labor, capital expenditures on education and highways	highways: 0.045–0.044 education: 0.16 –0.072 significant	returns to scale 1.04; cannot reject increasing returns to scale
Eberts (1988)	Translog production function	cross-section, manufacturing, 1958–78, 38 metropolitan areas	0.04 significant	CRS;[c] public and private capital are substitutes, public capital and labor complements

Table 1- continued

Author	Specification of Functional Form	Data	Elasticity[a]	Comments
Tatom (1991)	Cobb-Douglas production function including energy price, with first differences	time series 1974–87, business sector	0.146 insignificant	CRS[c]
Ford and Poret (1991)	TFP regressions[b]	time series and country cross-section, US and 11 OECD countries	half of countries; significant effect after 1960; mixed support of Aschauer results	
Hulten and Schwab (1991)	TFP regressions[b]	cross-section, time series, regional study of snow–sun belt, 1970–86, gross output value added	public capital insignificant in all regressions; private capital insignificant in gross output; regression significant in value-added implying scale 0.88	

[a] Elasticity refers to the percentage increase in some variable that will arise from a 1 percent increase in the level of infrastructure capital. For example, Aschauer estimates that a 1 percent increase in infrastructure leads to an increase of 0.36 to 0.39 percent in aggregate private sector output. The terms "significant" and "insignificant" indicate whether the reported estimates are, in a statistical sense, significantly different from zero.

[b] TFP is total factor productivity growth; for an explanation, see the later section of text headed The Growth-Regression Approach.

[c] CRS is constant returns to scale.

[d] Endowment refers to the level of economic development measured by state income level and the amount of public capital in the state. A high endowment state is California; mid-endowment states include Oklahoma and Kansas; low-endowment states include Arkansas and Mississippi.

Sources: Gillen 1996; Nadiri 1998.

line of argument; her results generally support the proposition that public infrastructure capital has a strong and significant effect on productivity growth.

The basic conclusion from these studies is that public capital is deficient. Critics quickly pounce on their claim of a 60 percent rate of return to public infrastructure investment, saying it is too high. Subsequent analysts argue the Aschauer/Munnell results reflect correlation rather than causality. This criticism has led to revisions about the relative importance of public capital. However, the basic thesis has not been refuted.

What has the production function approach contributed to our understanding of the role of public capital in economic growth? There seems to be a consensus that the earliest estimates based on aggregate US time series were "too high." The estimates from the state-level data indicate that the impact of public infrastructure investment is much smaller and that the specific composition of public capital matters. When the unit of analysis is on an even finer grid, two studies (Boarnet 1997; Chandra and Thompson 2000) have shown that, at the level of counties within states, the effect of such infrastructure investment is to redistribute economic activity rather than to generate any net increase in aggregate output.

The statistical evidence is that core public capital investment (for example, highways) is more significantly related to output growth and productivity than is noncore. Comparisons across 96 countries (Canning, Fay, and Perotti 1993) show normal or above-normal rates of return to transportation infrastructure investment in developed economies and lower returns in developing and underdeveloped economies. But this study does not make it clear that the direction of causation runs from investment in public capital to output; it could easily run the other way.

The Cost-Function Approach

Although production-function analyses provide a useful first look at linkages between infrastructure investment and productivity growth, they do not offer detailed consideration of the effects of public investment on the economic decisions and performance of

the firm. Production-function analyses omit input prices that affect factor utilization. The approach is a purely technical specification of the relationship between inputs and outputs, not a behavioral one. It does not consider the behavior of the firm in selecting input combinations or the level of output on the basis of the productivity and the prices of the different factors used in production. One result may be biased estimates of production-function coefficients.[8]

In response, some analysts suggest the use of cost or profit functions.[9] With cost-function methods, one can trace the effect of infrastructure investment on a firm's production structure and performance in considerable detail. It becomes possible to assess the effect of technical change, to see scale economies, and to predict the induced demand for employment, materials, and private capital stock (Nadiri 1999).

The cost-function approach thus provides a richer menu of analytical statistics. It allows for explicit characterization of the optimizing behavior of the firm, without loss of information relative to the production-function approach. Perhaps the most important advantage is the ability to investigate explicitly the relationships among inputs. Using a cost function, one can measure the direct effect of public capital by the magnitude of a cost reduction due to an increase in the level of that capital (such as transportation infrastructure). The indirect effect is provided by the cost savings from the increased productivity of other factors that are complementary to public capital. The demand for such complementary factors should increase in production.

Despite the methodological promise of the cost-function approach, however, studies using it produce mixed results. They do not agree exactly about the influence of publicly financed capi-

8 When firm optimization is explicitly considered, the marginal product conditions should be estimated in conjunction with the production function. Failure to do so results in biased parameter estimates.

9 Profit or cost functions are not used more than production functions for several reasons: they require much more data, they do not directly address the issue of public capital as an input, and production function estimates are easy to interpret. Furthermore, the data required for cost functions are available only for manufacturing.

tal on productivity. Some differences may be due to analysts' using different sets of data and evaluating at different levels of aggregation (metropolitan, state, national, or industrial). Differences may also arise from making different assumptions about the optimizing behavior of firms and the specification of cost functions.[10] Moreover, various analysts use different definitions of public infrastructure; some focus on core infrastructure, such as highways and water and sewer systems, while others use the total stock of public capital.

In general, cost-function studies find that infrastructure contributes to output growth, but the effect is smaller than production-function analyses suggest. Also, cost-function analysts find evidence that infrastructure capital has an important influence on the demand for private sector inputs, such as labor, materials, and capital. Most of the studies determine (as noted later) that, holding constant the level of output, substitution takes place between public infrastructure capital and private inputs.

Oum and Waters (1999) identify a methodological issue that earlier researchers seem to have ignored. They point out that some studies (Aschauer 1989a; Munnell 1990a) analyze infrastructure investment's effect on the level of *private* sector output, while most subsequent studies analyze the effect on gross domestic product (GDP), which includes *government* spending.[11] The issue here is that interpretation of the results differs fundamentally according to whether one is measuring private sector output or GDP. When GDP is the dependent variable, a positive elasticity of public infrastructure is insufficient to show any need for additional investment in it. One must compare the *marginal* products of government infrastructure investments with those of the private sector to determine where expansion is called for. On the other hand, if private sector output is the dependent variable, a positive coefficient on it is all that is required to show the positive contribution of public infrastructure to economic growth.[12]

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10 Many studies use either the translog or generalized Leontief functional forms.

11 In national income accounting, government spending, including infrastructure investment, is part of GDP by definition.

12 It goes without saying that the relative values of the returns to public and private spending should be compared.

Not surprisingly, three Canadian studies yield different results. Wylie (1995), using aggregate data, shows a substantial return to investment in infrastructure. On the other hand, Gillen (1998), using both national and provincial data, finds results consistent with a low (though positive) return to public capital. This outcome is in accord with Nadiri and Mamuneas (1996), who find that public infrastructure does shift the private cost function downward, but the movement is smaller than earlier analysts predicted. Furthermore, the downward shift would have been greater with the investment in private rather than public capital.

The third study, by Khanam (1996), uses provincial panel data to examine highway infrastructure capital *vis-à-vis* output growth and productivity in the Canadian goods-producing sector (excluding services) and reports results for provinces, rather than for Canada. Her results, consistent with those of Gillen (1996), are that highway capital has a positive and statistically significant impact on the Canadian goods-producing industry. However, her results also show that, except in British Columbia and Ontario, highway capital is contributing less and less to output over time.

Some Important Questions

Whether analysts base their studies on the production function or the cost function, many of them touch on some key issues. So far, the findings are often inconclusive.

The Relationship of Public Capital and Private Inputs. Public and private capital are complements in production if an increase in the latter raises the marginal product of the former, and substitutes if an increase lowers that product. This relationship is important since, if the two are complements, investments in public capital will lead to increased private investment; the opposite is true if they are substitutes. Studies by Munnell (1990b), Eberts and Gronberg (1988), Nadiri and Mamuneas (1991), Lynde and Richmond (1992), Shah (1992), and Aschauer (1989a; 1989b), for example, provide conflicting results, but it appears that at least part of the infrastructure stock is complementary with private capital.

The empirical consensus is that public capital and labor are substitutes, meaning that an increase in public capital investment can lead to reductions in employment since firms will substitute public capital for labor. However, the consensus is by no means complete. For example, Nadiri and Mamuneas (1996) estimate the cross-elasticity between public capital and the demand for labor to be approximately –1.4, implying that the two are substitutes, while Lynde and Richmond (1992) estimate an elasticity of approximately +0.45, implying that they are complements. Berndt and Hansson (1991), using Swedish data, agree that the two factors are complements, but Shah (1992), using Mexican data, finds that they are substitutes. In brief, the relationship between public and private capital is not clearcut.

Optimal Investment in Public Capital: Another important question is whether public authorities are making optimal decisions about additions to public infrastructure. Conceptually, the optimal amount is defined such that the sum of the marginal benefits to producers and consumers of any additional unit of infrastructure is equal to the marginal cost of providing this unit. Equivalently, in looking at the optimal distribution between public and private capital, one should use the same rule: the *social* rates of return to incremental public and private investment should be equal.

Nadiri and Mamuneas (1996) calculate a return to public capital of 7 percent while the return to private capital is 9 percent.[13] This result suggests that more investment in private capital rather than in public capital should take place. On the other hand, Morrison and Schwartz (1992) compare a calculated return to public capital with a user cost and find infrastructure investment has been too low; Shah (1992) comes to the same conclusion. In both papers, the calculated return to public investment is marginally higher than the return to private investment. (A higher return suggests diversion from private sector to public sector investment.) However, Morrison and Schwartz imply that the amount of public capital is

13 The authors argue that this calculated public return is biased downward since it is based on data for only a small subset of the economy's productive sector.

wrong because incremental benefits from investing in public capital still exceed the incremental costs.

Regional Distribution of Infrastructure: Two important studies identified earlier examine the issue at a local level by using data from the US county level. Their interest was in exploring a finding of Holtz-Eakin (1992) that investments in public capital have no spillover effects between US states. Boarnet (1997) examines the relationship between transportation investments and local economic development for all counties in California over the 1968–88 period. He argues persuasively that state-wide data reveal few if any measurable gains from infrastructure investments. However, when examined at a local or regional level, the data show some areas gaining and some losing with such investments. In the studies described above, the analysts report a wide range of output values, but those who took care with modeling and econometric estimation find results close to zero, meaning that such investments produce few measurable positive economic impacts. Nonetheless, one must remember that many investments are made to avoid negative spillovers, such as losing economic activity — jobs, income, and private investment — to neighboring cities, counties, or regions.

Spillovers can also be positive from the network effects of improvement in local areas. In a study of highway infrastructure investment in Los Angeles, Boarnet (1995) explores the effects of an increase on other California counties, both adjacent and more distant. Some lost and some gained. When aggregated to the state and federal level, the net effect was zero. It appears that such investments redistribute economic gains, shifting them from one region to the other.

Chandra and Thompson (2000), using data that cover the entire United States for the 1969–93 period, find that investments in interstate highways raised economic growth in the counties the roads passed directly through. This growth, however, came at the expense of adjacent counties, which suffered a decrease in economic growth. The authors conclude that regional highway investments assist nationally oriented industries, such as manufacturing, but merely lead to reallocation of economic activity among regionally oriented industries. This finding reaffirms Boarnet's conclusions that such

public capital investments redistribute rather than augment overall productivity.

Lessons Learned

From a review of the production- and cost-function literature summarized in Tables 1 and 2 , one can draw several conclusions. First, the preponderance of evidence suggests that infrastructure capital contributes to growth in aggregate output, that it reduces costs, and that it increases profitability in the manufacturing sector. The magnitudes of these contributions, however, vary considerably from study to study. Furthermore, the extrapolation of the results from manufacturing to other sectors is open to question.

Second, analysts agree that the original Aschauer estimates of the magnitude of infrastructure capital's contribution to output and productivity growth are too high. The output elasticity of infrastructure capital at the national level in the United States is probably in the range of 0.16 to 0.25. State and metropolitan elasticities of approximately 0.06 to 0.20 are plausible.

Third, a majority of studies indicate underinvestment in public infrastructure capital; the degree varies among them. Most of the cost-function studies suggest that private capital and infrastructure capital are substitutes, although some report that they are complements. The recent work of Nadiri (1999) indicates that public and private capital returns have been converging, implying that underinvestment in public sector infrastructure may no longer exist. Also highway capital, like most public capital, is underpriced, a situation that can lead to excess use.

Fourth, the results of highly disaggregated studies examining the redistributive effects of public capital (highway) investment are consistent with the results of aggregate studies and provide insight into who gains and who loses. The key result is that highway investment redistributes economic activity, and the gainers are more or less offset by losers; the net gain is zero. This result, coupled with the conclusion that, at both the industry and national level, the elasticity of output with respect to private capital is larger than it is with respect to total highway capital by a factor of two

during the 1960s through the early 1990s and by a factor of about four over the 1981–91 period, provides support for a policy of *not* investing in infrastructure in the way the United States is doing — and Canada seems to be following.

Infrastructure and Economic Growth Theory

The previous sections view the relationship between infrastructure investment and economic growth through the traditional lenses provided by cost-benefit analysis and production-function and cost-function estimation. These analytical frameworks are built on the traditional neoclassical model in which technology is taken as exogenous and factors are paid the value of their marginal product. In the dynamic neoclassical framework, as typified by the Solow-Ramsey growth model, these assumptions lead to the striking conclusion that economic growth, defined as *long-run* growth in per capita income (or, equivalently, average labor productivity), is independent of policy variables such as the savings rate or the level of public sector investment. An economy that has reached its optimum capital-to-labor ratio has a GDP growth rate equal to growth in the labor force. Real incomes can increase only if labor productivity increases. Policy variables can affect transitional growth rates, but not long-run ones. A result is that government can have only short-term effects on real growth and should focus on policies that increase labor productivity.

Since the mid-1980s, however, two significant developments, both directly opposed to the view of policy that emanates from this perspective, have had important implications for policies toward public sector infrastructure. First, the new growth theory pioneered by Lucas, Romer, Helpman, and others posits that the *rate of productivity growth* directly depends on the *level* of some policy variable, such as the level of education of the workforce, the amount of R&D investment, the amount of highway investment, the savings rate, the tax rate, or the level of public sector investment. Second, and accompanying the new growth theory, has been the appearance of an extensive statistical literature based on cross-sections or panels of the comparative international growth experi-

Table 2: ***Cost-Function Estimates***

	Description			Direct Effect		Indirect Effect
Author	**Geographic Unit of Analysis**	**Cost-Function Specification**	**Definition of Public Capital**	**Cost Changes**	**Labor**	**Capital**
Berndt and Hansson (1991)	Sweden: private sector, 1960–88	variable cost-labor-requirement function	core public capital	cost savings unclear	short-run complements	—
Conrad and Seitz (1992)	West Germany: manufacturing, construction, trade, and transport, 1960–88 time series	cost translog and MR=MC[b]	total, adjusted with capacity utilization rate	cost savings	substitutes	complements
Deno (1988)	USA: 36 SMSA manufacturing industries,[a] 1970–78, pooled	profit truncated translog	highway, water, and sewer; adjusted by the % of population employed by the sector	profit increase elasticity = .08 to 0.5	gross complements; elasticity = 0.1 to 0.4	gross complements; elasticity = 0.11 to 0.4
Keeler and Ying (1988)	USA trucking industry, 1960–88 regional, pooled	cost translog	highway stock	cost savings	—	—
Khanam (1996)	Canada: 1961–94, aggregate and provincial-level data	translog	total core and highway	cost savings	substitutes	complements
Gillen (1998)	Canada: 1961-96, aggregate and provincial-level data	log-linear and translog	total core and highway	cost savings	substitutes; elasticity = –0.16	complements, substitutes; elasticity = –0.17

Lynde and Richmond (1992)	USA: nonfinancial corporate business sector, 1958–89 time series	cost translog P = MC, and CRS[b, c]	total federal and state	cost savings	substitutes; elasticity = −0.45 to −0.49	complements; elasticity = 0.71 to 0.90
Lynde and Richmond (1993)	UK: manufacturing sector, 1966: Q1–1992: Q2 value-added	cost translog	total	cost savings	—	substitutes
Morrison and Schwartz (1991)	USA: manufacturing by state, 1971–87, pooled by region; state-specific effects	variable cost, generalized, Leontief P=MC[b, c]	core	cost savings elasticity = −0.10 to −0.27	—	—
Nadiri and Mamuneas (1991)	USA: manufacturing, 12 2-digit industries, 1955–86 pooled industry-pecific effects	cost translog CRS for private inputs[c]	total stock adjusted with capacity utilization rate	cost savings elasticity = 0 to −0.21	substitutes; elasticity = 0 to −1.4	substitutes; elasticity = −0.02 to −1.4
Seitz (1992)	West Germany: 31 2-digit industries 1970–89, pooled industry-specific effects	cost generalized Leontief	public roads, length of motorway system	cost savings	substitutes; elasticity = −.0004	complements; elasticity = 0 .03 to 0.04
Seitz (1994)	West Germany 31 2-digit industries 1970–89, pooled industry-specific effects	cost generalized Leontief	total core	cost savings	substitutes; elasticity = −0.15 to −0.13	complements; elasticity = 0.34 to 0.86
Shah (1992)	Mexico: manufacturing sector, 26 3-digit industries pooled	variable cost translog	total adjusted by industries' output %	cost savings	complements; elasticity = 0.006	substitutes; elasticity = −0.002

[a] SMSA = standard metropolitan statistical area.

[b] MR = marginal return; MC = marginal cost.

[c] P = price; CRS = constant returns to scale.

Sources: Gillen 1996; Nadiri 1998.

ences of countries in the post–1960 period. This literature identifies the rate of economic growth as correlated with a number of variables, including the rate of savings, the level of investment, inflation rates, the degree of openness of the economy, population growth, and others. This statistical literature leaves unresolved important issues about the causal links running between economic growth and the variables that would be robustly correlated with it. Nevertheless, some important empirical conclusions emerge, and they bear directly on the role of infrastructure, both public and private, in economic growth.

Infrastructure and Endogenous Growth

One version of endogenous growth theory is the AK model typified by a class of models introduced by Lucas (1988); the other is the Helpman-Romer model (Romer 1989), based on an endogenous process of productivity growth. Some investigators find at least some empirical support for both versions, and these results bear directly on the role of public sector investment.

In the AK model, all factors of production can be endogenously accumulated. Unlike the Solow-Ramsey models, it places no constraints on aggregate growth by an independently determined supply of either the labor input or natural resources. For example, the theory takes the view that the proper interpretation of the labor input is as a flow of services generated by a stock of "human capital," which is endogenously determined over time by investments in training or education. This type of model yields the conclusion that an increase in the savings rate in public capital increases the steady-state growth rate (or the growth rate of per capita permanent income) in the economy with an elasticity approximately equal to the elasticity of public capital in the aggregate production function.[14] If, for any reason, the formation of public capital is too low relative to that of private capital, the potential returns to shifting savings toward public capital can be quantitatively substantial.

14 In the literature previously discussed, these elasticities are estimated to be in the range of 0.02 to 0.20.

In contrast, the Helpman-Romer model focuses primarily on R&D as a potential source of endogenous productivity change in the economy; other authors stress the role of human capital as an equivalent mechanism. In both cases, the potential for long-run endogenous growth arises because of the intertemporal spillovers in the process of knowledge creation. These spillovers occur because the stock of knowledge existing at a point in time is assumed to be a public good — in the Samuelson sense that the marginal cost of its use is zero and access is universal — and it becomes an input into the production of new knowledge. Intuitively, one sees that an idea today is potentially available at zero marginal private cost and is useful to anyone generating knowledge tomorrow. Human capital and R&D play roles as the private inputs that go into the creation of new knowledge; they are complementary inputs to the existing stock of knowledge. One can easily make similar arguments for transportation, communication, and health infrastructure if they presently operate as important limits to the general process of knowledge creation and dissemination.

Here arises an important question: Does new infrastructure lead to lower costs within a given set of production possibilities, or is its effect more extensive in that it expands the production possibilities from any given set of inputs? If infrastructure serves essentially to lower costs, then competitiveness is crucial; its extent will determine whether the lower costs generate a broad increase in output across the economy or merely high rewards for a select few who have access to the new infrastructure.

Implications and Contrast

If either the AK or Helpman-Romer model finds strong and lasting empirical support, the policy significance would be fundamental. In practical terms, however, it is difficult to distinguish these new growth theory effects from more traditional growth effects. In the traditional growth model of the Solow type amended to include public infrastructure, the production function is given by

$$Y = F(K, G, L),$$

where K is private capital, G is public infrastructure, and L is a primary factor labor. Constant returns to scale of the production function in all inputs and exogenous determination of labor force growth are jointly sufficient to imply the existence of a steady-state growth rate equal to the growth of the labor force.

One's intuition here is that existing production conditions imply an — admittedly hard to determine — optimum ratio of K to G to L that, in turn, maximizes the per capita productivity of the economy. Given an independently determined rate of labor force growth, changes in the rate of investment in either K or G can have no effect on the maximum long-run or steady-state growth of per capita income. If, for example, something generates enough additional K and G to result in deviations from the optimum ratio of K to G to L, the economy has too much K and G relative to L. The marginal productivity of the additional inputs will fall below their marginal costs, with the short-run result of per capita income lower than the potential. In the long run, either the marginal product of labor will rise or the marginal product of K and G will fall. Without clear technological change, the steady-state growth will return to its previous path.[15]

An important difference exists between, on the one hand, theoretical specifications in which infrastructure externalities spill over to spur on the knowledge-creation process and, on the other hand, the more conventional static production function in which the level of infrastructure has an effect on the level of output. An Aschauer-type production function, for example, is consistent with the *level* spillover channel for public capital but not with a *dynamic* specification. In fact, if a traditional production function regression of the

15 Additions to private capital or public infrastructure can, however, have a substantial transitional effect. An increase in the fraction of output devoted to public capital formation has a temporary but positive effect on the growth rate of per capita income under many circumstances. It is possible to show that the initial increase in the growth rate is approximately proportional to the factor share parameter of public capital in the aggregate production function. Furthermore, the half-life duration of the out-of-steady-state impact is directly proportional to the share parameter. In practical terms, the transition period is estimated at 10 to 20 years when the share of capital in output is in the 0.33 range and much longer for more comprehensive definitions of capital that include human capital and public infrastructure.

Auschauer sort is used but the true model is as given by an endogenous productivity growth specification, one would not expect to find much in the way of contemporaneous links between changes in output and changes in public capital. The dynamic growth effects may take much longer to observe.[16]

Each of the theories described has a major issue that needs to be addressed before one can take it seriously. First, in the AK models, just how plausible are the technological assumptions that require nondecreasing returns to all factors of production and the absence of any primary factors in the production function? The existing returns-to-scale evidence offers little that relates to the public infrastructure issue. Economists have made some estimates of aggregate production functions that include physical and human capital, but they do not typically cover infrastructure capital. Second, in the endogenous productivity models, what is the precise externality which causes a spillover from public infrastructure? These links are never made precise in the literature discussed earlier, and the same is true here. The models therefore appear to be less than helpful in exposing the relationship between public capital and economic growth.

The Growth-Regression Approach

During the past decade, economists have made considerable headway on the empirical determinants of economic growth, measured as the rate of increase in per capita real income, appropriately adjusted for purchasing power parity (PPP). From the early time-series work on production functions and growth accounting exercises, analysts identified total factor productivity growth (TFP)[17] as

16 Thus, the growth-regression approach may be a research strategy more promising than growth accounting based on an assumed neoclassical link between output and public capital.

17 TFP is the sum of all factors of production, a measure of the growth in outputs relative to the growth in inputs. It includes all products produced by forms and all inputs used in the production of those outputs. In contrast, partial factor productivity measures the amount of output per unit of a particular input, such as labor.

the most important determinant of economic growth rates in most countries. However, they left determinants of TFP growth unexplained. This quite unsatisfactory state of affairs has given rise to an alternative methodology, which seeks to identify the sources of long-term growth. It is now known as the growth regression approach.[18]

The Methodology

The primary input to a growth regression is a data set based on the growth experience of a large number of countries from roughly 1960 to more recent years. These data are used in a cross-sectional or a panel regression with the growth rates of individual countries on the left-hand side of the regression and a number of explanatory variables on the right-hand side. The growth regression literature started more or less at the same time as the new growth theory.[19]

Not surprisingly, one finds considerable diversity both in the growth experience of countries and in the extent of public sector investment in their economies. From the 1970s through the 1980s, the industrialized world saw a considerable falloff in public sector investment, with many countries showing declines of 2 percent or more in the share of GDP devoted to public sector investment. More recent statistics show substantial variation, even among the member countries of the Organisation for Economic Co-operation and Development. In 1992, for example, public investment was 1.3 percent of GDP in the United Kingdom but 5.8 percent in Switzerland (Baumol, Blackman, and Wolff 1995).

These trends, which were driving the Auschauer debate, spilled over into the growth-regression literature.

The remarkable cross-sectional variation in individual countries' growth rates has turned out to be a rich source of information for investigation of the determinants of growth. Early work by

18 A good illustration of this literature is Hickman (1992).

19 Which provides a convenient theoretical rationale for the explanatory variables that the growth-regression approach commonly includes on the right-hand side, variables that could not be justified by either neoclassical growth theory or traditional production-function approaches.

Barro (1991) and others has been replicated using an assortment of econometric techniques and variations on data construction, country samples, and timing. With a few exceptions, investigators agree that a handful of variables are significantly and strongly correlated with growth in per capita income (see Hickman 1992). These variables include

- the share of investment in GDP (the higher the share, the greater the growth rate);
- the degree of the economy's openness to trade and investment (the more open the better);
- the level of the work force's education (the higher the better); and
- the initial level of income (the lower the initial per capita income, the greater the growth rate — that is, the catch up effect).

Some more recent studies use panels of TFP growth rates, rather than simply average labor productivity, as the independent variable, and find that similar variables explain TFP growth. However, because TFP growth nets out growth in the magnitude of the factors available, this approach removes, by construction, a lot of what is of interest in the growth process.[20]

TFP growth analysis creates some other difficulties. For example, high investment rates, including those for public sector investment, turn out to be strongly correlated with per capita income growth. The major difficulty here is the direction of causality. Which comes first: high investment rates or per capita income growth? The general conclusion of the literature is that returns to capital formation are ultimately diminishing, although the rate of decrease appears to be very slow.

This evidence tends to weigh against the AK model of economic growth. It does not, however, eliminate the possibility that important externalities are linked to physical capital accumulation. DeLong and Summers (1990) identify what appear to be important growth externalities for investment in machinery and equipment,

20 Obviously, countries can grow through factor accumulation, and in many cases explaining input growth is as important as explaining TFP growth.

(investment in structures or in land does not seem to have the same effects). The implication of this work, which appears to stand despite critics' numerous attempts to overturn the results, is that social rates of return to equipment investment are extremely high — on the order of two to three times private rates of return. A possible explanation for this result is that equipment investment is highly correlated with industrialization and with technology transfer in many countries.

The Empirical Literature

The interesting and apparently robust results on investment and growth leave us uncertain about the precise role that investment in public infrastructure plays in economic growth. Studies in the growth-regression tradition yield mixed results. Barro (1991), for example, finds that the ratio of public investment to GDP is positively but insignificantly correlated with growth. But Easterly and Rebelo (1993) determine a positive and significant impact of general government investment on growth; they use the share of public investment in transport and communications as the public capital variable and find it to be robustly correlated with growth but with surprisingly high coefficients.[21]

In contrast, Devarajan, Swaroop, and Zou (1996) report a negative and significant relationship between the ratio of total expenditure on transportation and communications to the level of GDP for a sample of 43 less-developed countries. Sanchez-Robles (1998), examining some Latin American economies, finds some evidence of growth effects from indexes of physical infrastructure but negative effects when he uses expenditure share measures. He attributes this discrepancy to infrastructure's having a potentially transitory effect on growth rates and discounts the possibility of its having permanent effects.

The growth-regression literature attracts several criticisms beyond impatience with its apparently contradictory results (see,

21 The estimated coefficients are significantly higher than similar estimates in a number of other studies.

for example, Temple 1999). First, many authors derive their results by imposing parameter constancy across a wide range of countries, from Switzerland to Zimbabwe. If parameters are not constant (for example, across different stages or levels of development), the policy implications on variables such as public sector infrastructure may be incorrect or misleading. Second, the estimates include both the direct and the indirect effects of public infrastructure. In other words, the elasticities mix the growth effects induced through direct factor input changes, through the static externality effect, and through the dynamic knowledge-creation externality. Third, the estimates do not distinguish between the transitional growth effects of policy (movement from one steady state to another) and steady-state growth effects, although the implications of these alternatives may be extremely important. Fourth, this type of work presents severe data problems, particularly in a sample involving developing countries.[22]

Pritchett (1997) severely criticizes the use of public sector investment data, arguing that they have little to do with useful public capital stocks, even in apparent steady-state situations. His point is that much of measured public capital in developing countries is nonproductive due to what he calls the pyramid phenomenon (a lot of public spending goes into showcase "monuments" that have little actual productive value to the economy). Basing his view on a review of projects financed by the World Bank, he cites, for example, an African country that had 31 projects involving roughly $1 billion in expenditures for which the median *ex post* rate of return was zero.

Evaluating fiscal policy by means of structural macroeconometric models and applied general equilibrium models has a long history. Yet the evaluation of public infrastructure provides few examples of their use. This lack is surprising because almost everyone agrees that simultaneity among infrastructure investment, output growth, and productivity growth is a serious problem. Structural

22 The growth regressions actually put on the right-hand side not the stock of infrastructure but public investment (divided by GDP). Using a poor proxy to compensate for lack of data can create a misspecification of the equation.

modeling would be a natural approach to take. The problem remains; most of the applied policy literature based on external effects offers few reliable estimates of the underlying structural parameters, and thus the uncertainty surrounding the results is substantial.

Nevertheless, we have some quantitative modeling based on modern growth-theory methods, and the results are surprising, even with relatively modest assumptions as to the output elasticity of public capital. A prominent paper in this literature is Baxter and King (1993). The results are noteworthy in that they demonstrate how wrong static intuition can be about the long-run effects of policy changes. Using a calibrated dynamic general equilibrium model with full employment, market clearing, and rational expectations, the authors examine the impact of changes in the share of GDP devoted to public investment within a balanced-budget fiscal framework. In particular, their model uses distortionary income taxes to finance government revenues, including public sector investment.[23] With aggregate increasing returns, dynamic models display very complicated and typically lengthy transitions. The authors summarize their results by specifying what they call the short-run and the long-run multiplier of productive public spending.[24] An important parameter in the model is the intertemporal substitution effect in labor supply; changes in public capital affect the real interest rate, which, in turn, influences individuals' adjustment of their labor supply over time. The simulations show an amplification effect that works through the real interest rate channel. An increase in public capital raises the real interest rate, tending to reduce consumption and increase labor supply in the short run; in addition, it stimulates additional private sector investment. The net effect is a multiplier on the initial productivity increase. The greater the degree of intertemporal substitution, the larger the multiplier tends to be.

23 The specification of the technology side of the model is very close to the Auschauer-type specifications with an elasticity of private sector output with respect to public capital of 0.05 and share in GDP in the benchmark of 0.05 and aggregate increasing returns in all factors.

24 The terminology is confusing since the classical model has used virtually no Keynesian aspects.

The numbers Baxter and King get are quite interesting. They find significant short-run and long-run multipliers through looking at simulations that involve a permanent 1 percent increase in the amount of public capital expenditures each year. The short-run multiplier is very sensitive to the short-run impact on labor supply, which hinges on the intertemporal substitution effect already described. The mid-range estimate is around 1.10, although for some elasticity values it goes as high as 1.37. The-long run effects tend to be smaller but differ considerably from what a static or partial equilibrium calculation[25] would suggest. Using alternative values of the output elasticity of public capital from .01 through 0.4 (a range corresponding to that found in the literature), the long-run value of aggregate output change with a public capital change ranges from 1.45 through 8.00! In brief, the long-run effects on output levels are significant and very sensitive to the output elasticity. An implication is that growth rates rise significantly during the transition. One must be careful in drawing welfare conclusions. The strong intertemporal aspects of the model imply that, in the short run, consumption falls and labor supply increases in response to the increase in public capital, changes that would tend to dampen positive welfare effects.

Overall, the new dynamic general equilibrium models offer some insights, but this research is limited. Certainly, we have few good examples of these models' fully integrating public capital, particularly infrastructure. Even in the Baxter and King (1991) paper, we have strong *assumptions* of continual increasing returns, a complementarity between public and private capital, and no congestion. Yet the important implication of this paper is similar to much of what we have learned elsewhere in the application of general equilibrium methods to policy: partial equilibrium reasoning can be invalid. Moreover, when a policy affects investment decisions, a static analysis can yield results that are quantitatively different and potentially misleading relative to those provided by a correct dynamic general equilibrium evaluation. The paper is, however,

25 For example, simply taking the estimating marginal product of public capital as fixed and holding all private inputs constant — the usual shadow price calculation of cost-benefit analysis.

important in illustrating the dependency of the general equilibrium methods on good empirical estimates of the relationship among factor inputs. The earlier review of these values suggests the Baxter and King work is a beginning, rather than a prescription for policy purposes.

Summary and Conclusions

The policy issue is whether government should invest more in public capital, particularly transportation infrastructure, to promote economic growth. Cross-sectional and panel studies that attempt to measure the marginal contribution of government investment via simple models offer evidence that is mixed and conflicting, due partly to data problems and partly to methodological differences among analysts. Nonetheless, on balance these studies do not provide a strong case for expanding public capital investment.

Given the ambiguity of the results generated by simple models, the influence of public investment in infrastructure — particularly transportation infrastructure — is better understood in the context of a general equilibrium regional economic model. Why go to this extra effort? Public investment affects output directly because expenditures on infrastructure are a part of the *regional* economy. It also has indirect or secondary effects: it becomes an input into firms' production functions and may improve the productivity of other input factors, such as labor and private capital. In the presence of such complementarity, an increase in public infrastructure may increase the return to private infrastructure investment and thus encourage more of it. Public and private capital may, however, also be substitutes. Thus, in the presence of full employment, the expansion of public infrastructure investment may displace some private sector investment. General equilibrium regional models, therefore, are useful only for short-run and regional decisionmaking, and they offer no insight into the optimal balance between private and public capital.

The new growth theories, and their empirical counterparts in growth regressions and dynamic quantitative modeling, certainly suggest the potential for a link running from public infrastructure

investment to additional economic growth. My view is that this potential remains an unproven hypothesis, though one that warrants more research. Certainly, simply bumping up social rates of return on infrastructure projects would be an imprudent response to these macroeconomic investigations. That said, this new literature certainly reinforces the case to be made for devoting more resources to infrastructure cost-benefit evaluations of potential external and dynamic effects.

The failure to use multiple-equation (general equilibrium) approaches raises doubts about the direction of causality. Is it from public capital to output or the reverse? Measurement of infrastructure input is suspect because secondary data and various proxies are the usual major data sources. Additionally, capital stock may be an inaccurate measure of infrastructure services. More accurately determining service quality might help research to incorporate issues such as the efficient use of infrastructure (for example, road pricing) that current studies do not entertain. Capital stock is also difficult to quantify and the perpetual inventory approach may not provide an accurate estimate.

On the basis of the literature reviewed here, should government change its policy to undertake once again more public capital investment in infrastructure? I say no. The most compelling argument is that such investment redistributes costs and benefits, rather than augments overall economic productivity. The literature offers no insights about the mechanism for translating increased public capital investment into economic growth. Furthermore, the literature shows that the return to private capital exceeds that to public capital and that we appear to have the right amount of the latter. The only caveat I make is that the comparison of public and private returns does not consider spillover effects. The enabling feature of public capital, while attractive in theory, is as yet only weakly supported by the evidence. Finally, the literature provides no guidance as to which instruments would be most effective in implementing an expanded policy. The various rail subsidy schemes the Canadian government has employed over the past hundred years provide ample evidence of failures.

The country's investment in public capital — highways, in particular — is huge, and all levels of government have an interest in

managing and maintaining that investment efficiently. Since provincial governments have primary jurisdiction over highways, what is needed is a closer pricing and funding link between urban areas which pay for benefits that are strictly urban in nature and respond to local costs. The current system of financing and subsidies has contributed to urban sprawl and reduced — in some cases offset — the productivity gains that would accompany public capital investment.

Having said all of this, do I think that policy should respond only to crises of shortages or should withdraw from net investment in public capital altogether? I can suggest neither course of action. To understand what is needed, policymakers must understand the role of public capital. It can replace private capital; it can be provided by government when private capital markets would undersupply it; and it can provide connectivity to communities. The last role may be a real public good in the sense economists understand.

It appears that what is required is an institutional change in the way public capital is funded and managed. The disconnect between user payments and investment has led to too much public capital in most cases and not enough in others. The potential undersupply of capital could be addressed through incentive contracts and financing subsidies, as could the public good aspect of public capital. The single most important change would be to charge user fees, thereby addressing questions of revenue, allocation, spillovers, shortages, type, and politics. It would link value with use and provide a better signal for investment. A clear link between benefits and costs and the identification of who benefits and who loses would, in the long run, have beneficial effects on trade as well as on urban form.[26]

26 The current political climate, in which select segments of infrastructure users are politically active in their attempt to reduce fuel taxes, may provide an excellent opportunity for moving from taxing inputs to pricing outputs.

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The Social Discount Rate in Canada

Mark A. Moore, Anthony E. Boardman, and David H. Greenberg

Roads, dams, bridges, airports, and other government-financed infrastructure projects are long-lived. They usually involve large up-front construction costs and then produce annual flows of recurring benefits, net of ongoing costs. These annual net benefits may accrue for several years, decades, or even generations.

When evaluating proposals for such projects, analysts must decide on the appropriate weights to apply to effects that would occur in different years. Given these weights and estimates of the annual net benefits, it is possible to determine whether the weighted sum of the future net benefits exceeds the present costs of construction — that is, whether the net present value (NPV) of the project is positive.

Most analysts apply weights that decline over time at a constant rate. The rate at which these weights decline is called the *social discount rate* (SDR).

Generally, for infrastructure projects, the costs occur early and the benefits occur late. The NPV of such projects declines with higher values of the SDR. A low discount rate may yield a positive NPV, implying that the infrastructure project should proceed, while a high discount rate may yield a negative NPV, suggesting that it should not proceed. Thus, policy recommendations about

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infrastructure projects (go versus no-go) depend crucially on the choice of the SDR.

Unfortunately, experts do not agree about the magnitude of the SDR, although some consensus is emerging. The main purpose of this essay is to suggest an appropriate rate for use in the evaluation of infrastructure projects in Canada.

The key issue in discounting is to decide on the weights society should apply to consumption that will occur in future periods relative to the same amount of consumption in the current period. These weights represent how much current consumption society is willing to give up in order to obtain a given increase in future consumption.

It is generally accepted that society's choices, including the choice of weights, should be based on individuals' choices. But three fundamental issues remain unresolved:

- Can market interest rates be used to represent how individuals weigh future consumption relative to present consumption?
- Does "society" mean only individuals who are alive today or does it include unborn future generations?
- Does society attach the same value to a unit of investment as to a unit of consumption?

Consideration of these issues means that there may not be a single discount rate that applies to all benefits and costs in all periods.

In this essay, we thoroughly review these issues, the theoretical circumstances under which there is agreement about the SDR, and current discounting practices in North America. We conclude with our best judgments about the most appropriate set of discount weights to use in particular situations. These weights should vary according to the length of the project, whether intergenerational issues are a concern, whether it will have large environmental or health effects in the future, and whether the costs and benefits affect consumption or investment. We present our best estimates for each situation, with upper and lower bounds that can be used in sensitivity analyses. Careful use of these rates can reduce the past arbitrary choices of discount rates and lead to better decision-making.

The first section briefly outlines the practical issues of discounting. The next section surveys discounting practices in North America and suggests that government-recommended discount rates have been trending down. Following come a review of the circumstances under which the choice of the social discount rate is clear, an explanation of why these circumstances do not obtain in practice, and a detailed discussion of eight alternative social discounting methods. We conclude with suggestions about the appropriate social discount rates to use in specific circumstances.

The Use of a Social Discount Rate

Discounting reflects the generally accepted idea that a given amount of real resources available today is worth more than the same amount of resources available in the future. This is because, through investment, one can transform resources that are currently available into a greater amount of resources in the future. Viewed somewhat differently, discounting is also needed because people prefer to consume a given amount of resources now rather than in the future.

The opportunity cost to society of \$1 in t periods in the future is $1/(1 + s)^t$ now, where s is the SDR. This amount, $1/(1 + s)^t$, is the *social discount factor*. When evaluating a government project, analysts weight costs and benefits to be paid or received t periods in the future by the social discount factor, thereby converting them into present values (PVs). These present values can be aggregated to yield the *net present value* (NPV) of the proposed project. A project with a positive NPV should be adopted, while a project with a negative NPV should not. When faced with alternative projects (in addition to the status quo), the one with the largest positive NPV should be selected.[1]

1 Some authors have proposed alternative selection criteria including the use of the internal rate of return, the payback period, or the benefit/cost ratio. Use of these criteria may or may not provide the correct answer. Only the NPV criterion always ranks projects correctly (Boardman et al. 2000, ch. 2).

An Example of Computing NPV

Consider a project with a life of n years. Let B_t denote the benefits arising in year t, and C_t the costs arising in year t ($t = 0, 1, 2, ..., n$).[2] The NPV of a project equals the PV of the benefits minus the PV of the costs:

$$\text{NPV} = \sum_{t=1}^{n} \frac{B_t}{(1+s)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+s)^t}. \tag{1}$$

Suppose a municipality is considering constructing a new pedestrian overpass across a busy street. The overpass would reduce accidents and increase the speed and flow of traffic. These benefits are estimated at $150,000 a year, including both cost savings to the pedestrians (the value of fewer accidents) and to vehicle users (the value of travel time saved). The overpass would cost $405,000 to construct and $50,000 to maintain each year. For simplicity, assume that the overpass would last only five years, after which it would be dismantled and scrapped at a cost of $30,000. Assume that the annual costs and benefits would occur at the end of each year, and there would be no other costs or benefits.

We calculate the present values at three different discount rates: 2 percent, 5 percent, and 8 percent. This information and the analysis are summarized in Table 1. Because this project has most of its costs up front, with positive net benefits occurring further in the future, the NPV increases as the discount rate decreases: the NPV is $39,174 if s is 2 percent, $4,442 if s is 5 percent, and –$26,146 if s is 8 percent. Thus, if the appropriate discount rate is 2 percent, the NPV is clearly positive and the municipality should proceed with the overpass, while if the appropriate rate is 8 percent, then the NPV is clearly negative and the project should not proceed. At a 5 percent discount rate, the project has a slightly positive NPV and should also be chosen.

2 Throughout we assume that annual benefits and costs occur at the end of each year. Thus, period 0 means immediately, period 1 means in one year's time, and so forth.

Table 1: ***The Net Present Value of a New Pedestrian Overpass, Using Different Discount Rates***

	Event	Benefits	Costs	Net Benefits
			(dollars)	
Year 0	Purchase and install	0	405,000	-405,000
Year 1	Annual benefits and costs	150,000	50,000	100,000
Year 2	Annual benefits and costs	150,000	50,000	100,000
Year 3	Annual benefits and costs	150,000	50,000	100,000
Year 4	Annual benefits and costs	150,000	50,000	100,000
Year 5	Annual benefits and costs	150,000	50,000	100,000
End of year 5	Liquidation	0	30,000	-30,000
			Present Value	
$s = 2\%$		707,019	667,845	39,174
$s = 5\%$		649,422	644,980	4,442
$s = 8\%$		598,907	625,053	-26,146

An alternative way to compute the NPV of a project is to compute the present value of the annual net benefits (NB). Those arising in year t ($t = 0, 1, 2, \ldots n$) can be written as $NB_t = B_t - C_t$. Now, the NPV of a project is given by:

$$\text{NPV} = \sum_{t=0}^{n} \frac{NB_t}{(1+s)^t}. \tag{2}$$

Notice that equation (2) produces the same NPV as equation (1):

$$\text{NPV} = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+s)^t} = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+s)^t} = \sum_{t=0}^{n} \frac{NB_t}{(1+s)^t}.$$

Thus, the present values of the annual net benefits are identical, using each of the three discount rates, to those shown in the last column of Table 1.

Real versus Nominal Discount Rates

In practice, market interest rates are stated in nominal terms, which reflect inflationary expectations. In contrast, real interest rates or real

dollars net out the effects of inflation on consumption. To illustrate the difference between nominal and real dollars, suppose an individual can invest $100 for a year at a nominal interest rate of 10 percent. At the end of the year, the return will be $10, but, if the rate of inflation is 4 percent, the investor will be able to purchase only approximately 6 percent more than he or she could at the beginning of the year. Thus, the individual will really be better off by only $6, not $10. While the nominal interest rate is 10 percent, the real interest rate, which reflects the real increase in consumption after taking account of inflation, is about 6 percent.

More formally, $1 invested today at a nominal interest rate of i yields $\$(1 + i)$ one year later. However, with an inflation rate of m during the next 12 months, $\$(1 + i)$ one year from now will buy only as much as $\$(1 + i)/(1 + m)$ does today. The real interest rate, r, is therefore defined by

$$\$(1 + r) = \$\frac{(1 + i)}{(1 + m)}.$$

Rearranging this expression gives the following formula for converting a nominal interest rate, i, to a real interest rate, r, when the expected inflation rate is m:

$$r = \frac{i - m}{1 + m}. \tag{3}$$

For example, if the nominal interest rate is 10 percent and the expected inflation rate is 4 percent, then the real interest rate is $[(0.10 - 0.04)/1.04] \times 100\%$, which equals 5.76 percent. Providing m is small, r is approximately equal to $i - m$. Thus, earlier we used a close approximation for r of 10% – 4% equals 6%.

When conducting *ex post* (after the project) analysis, one needs an index of past price increases. In practice, researchers usually use the consumer price index (CPI).[3] We follow this approach throughout this essay. Prior to 1998, however, the CPI generally overestimated the rate of increase in the cost of living by about 1.0 percen-

3 The most recent CPI figures and other price indices are available at the Statistics Canada web site, www.statcan.ca. For long-term historical Canadian CPI data, see Leacy (1983). For US CPI data, see www.bls.gov.

tage point per annum in the United States and about 0.7 of a percentage point per annum in Canada.[4] Thus, the reader should bear in mind that our estimates of the real social discount rate potentially understate the appropriate real rates by about 70 basis points.

When conducting *ex ante* (before the project) analysis, one needs an index of inflationary expectations. The current CPI is one possibility, but it reflects only past price increases. *The Economist* and most leading banks and brokerages provide better estimates of future inflation.

When computing the NPV of a project, one must measure benefits and costs consistently with the discount rate. If benefits and costs are measured in nominal dollars, then the analyst must use a nominal discount rate, but if benefits and costs are measured in real dollars, then the analyst must use a real discount rate.[5] Both methods result in the same numerical answer. To see this point, recall that the NPV for a project is given by equation (1). Suppose that these benefits, B_t, and costs, C_t, are in nominal dollars and i is the nominal interest rate. If b_t denotes real benefits, c_t denotes real costs, and the rate of inflation is m, then:

$$\text{NPV} = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t} = \sum_{t=0}^{n} \frac{(b_t - c_t)(1+m)^t}{(1+i)^t}.$$

Using equation (3), the NPV can be expressed in real dollars:

$$\text{NPV} = \sum_{t=0}^{n} \frac{b_t - c_t}{(1+r)^t}.$$

Analysis is often easier when using real dollars and a real discount rate. More important, using real dollars indicates whether ben-

4 See Moulton (1996) and the Boskin Report (Boskin et al. 1996). The estimate of the Canadian bias is based on private communication with Professor Erwin Diewert. Since the Boskin Report, the US Bureau of Labor Statistics has made innovations to its procedures that have reduced the measured US inflation rate by about 0.65 percent per annum.

5 To convert benefits or costs from real dollars to nominal dollars, multiply them by $(1+m)^t$. To convert a real interest rate to a nominal interest rate, solve equation (3) for i. To convert benefits or costs from nominal dollars to real dollars, multiply by $1/(1+m)^t$. To convert a nominal interest rate to a real interest rate, use equation (3).

efits or costs increase in real terms over time. Thus, this approach is more transparent. Throughout the remainder of this essay, we assume that benefits, costs, and discount rates are in real terms (as we did in the pedestrian overpass example).[6]

The Importance of the Choice of Social Discount Rate

As implied in the example of the pedestrian overpass, the choice of a particular value for the social discount rate can be decisive in determining whether a project has a positive or negative NPV. For example, in his paper in this volume, Martin uses cost-benefit analysis to evaluate six possible variants of a high-speed rail project along the Quebec-Windsor corridor. When he uses an SDR of 8 percent, all of the variants have positive NPVs. When he uses a 10 percent SDR (the rate currently recommended by the Treasury Board), however, only one variant still has a positive NPV.

The choice of SDR can also affect the ranking of projects. To see this point, consider a government agency that has only $100,000 to spend on one of three potential projects, whose annual net benefits are shown in Table 2. Choosing the lower discount rate (2 percent) would favor project C, while the higher discount rate (10 percent) would favor project B. Thus, the agency's choice of project depends crucially on the choice of discount rate.[7]

Generally, a low discount rate favors projects with the highest total benefits, irrespective of when they occur, because all the social discount factor weights are close to 1. Increasing the discount rate applies smaller weights to benefits (or costs) that occur further in the future and therefore weakens the case for projects with benefits

6 For more on the mechanics of discounting in practice, see Boardman and Greenberg (1998), a work on which this essay draws heavily.

7 It may initially appear that, with a constrained budget and the choice of several projects, a government can simply choose the project with the highest internal rate of return — that is, the discount rate that would result in an NPV of zero. This procedure is clearly incorrect. The example in Table 2 indicates that, in fact, the ranking of projects depends on the discount rate.

Table 2: ***Annual Net Benefits and Net Present Values for Three Alternative Projects***

	Project A	Project B	Project C
		(dollars)	
Year 0	–100,000	–100,000	–100,000
Year 1	30,000	100,000	0
Year 2	30,000	11,000	0
Year 3	30,000	11,000	0
Year 4	30,000	11,000	0
Year 5	30,000	11,000	160,000
		Net Present Value	
$s = 2\%$	41,404	39,103	44,917
$s = 10\%$	13,724	22,608	–653

that are back-end loaded (like project C) and strengthens the case for projects with benefits that are front-end loaded (like project B).

The Social Discount Rate in Practice

Currently, governments use constant discount rates, though they vary from country to country and sometimes from department to department. In practice, the rate used in the evaluation of an infrastructure project is usually prescribed by the appropriate government review agency.[8] In North American jurisdictions, the prescribed rates have tended to be fairly high, but they have been trending lower. For example, in the 1970s and 1980s, the US Office of Management and Budget (OMB), which guides the cost-benefit analyses of all US executive branch agencies, required most of them to use a real discount rate of 10 percent, a rate intended to approximate the opportunity cost of capital, measured as the real marginal before-tax rate of return on private investment. In 1992,

8 See Lyon (1990) for an excellent review of US federal discount rate policy to 1990.

the OMB revised this rate downward to 7 percent. This new rate was based on low-yielding forms of capital, such as housing, as well as high-yielding corporate capital.

The General Accounting Office (GAO) and the Congressional Budget Office (CBO), both of which are US Congressional oversight agencies, use lower rates, based on the US Treasury's borrowing rate. The CBO has estimated the real historical yield on US government securities at 2 percent and uses this rate plus or minus 2 percentage points. The GAO uses the existing average nominal yield on Treasury debt maturing between one year and the life of the project less the forecast rate of inflation.[9] The GAO uses the same rate for all applications, while the CBO and the OMB have a number of exceptions.[10]

A recent proposal by the US Panel on Cost-Effectiveness in Health and Medicine recommends the use of a real 3 percent discount rate for cost-effectiveness studies, with sensitivity analysis at rates between 0 and 7 percent (Weinstein et al. 1996).

Since 1976, the federal Treasury Board Secretariat in Canada has recommended the use of a real SDR of 10 percent, with sensitivity analysis at 5 and 15 percent (Canada 1976, ch. 11). The rationale for this rate draws extensively on research by Jenkins (1973; 1977). The Treasury Board sometimes allows much lower discount rates (0 to 3 percent) for health and environmental cost-benefit analyses, although this is not official policy. Currently, the recommended rate for Crown corporations in British Columbia is a real SDR of 8 percent (British Columbia Crown Corporations Secretariat

9 In December 1998, the US government's ten-year constant-maturity bond was priced to yield 4.65 percent, while the rate of US CPI inflation (all items) from December 1997 to December 1998 was 1.6 percent, yielding a 3.05 percent real discount rate. (See Internet website: bos.business.uuab.edu.)

10 In the case of asset divestitures, both the OMB and CBO use comparable private sector rates. If they did not do this, they would use a discount rate lower than the private sector, which would imply that the NPV of assets is higher in the public than in the private sector. The rule, assuming there are no efficiency differences between public and private ownership, would imply that government should own all income-producing assets and never sell any of them (Hartman 1990).

1993). The city of Vancouver recommends a real discount rate of 6 percent, although NPV calculations are not always required.[11]

At this point, the skeptical reader may ask why one should be concerned about the choice of SDR when bureaucrats use estimates varying from 0 to 15 percent. The brief answer is that society must decide whether or not to build the bridge (or whether to build bridge A or bridge B). Ultimately, the decision may be a political one. However, thoughtful analysis can help make decisions that produce more social benefits. Later in this essay, we provide social discount rates that are based on the current state of the art. Our suggested rates vary according to the specific circumstances surrounding a project. It may be quite reasonable to apply a low rate to one project and a high rate to another.

The Social Discount Rate in Theory

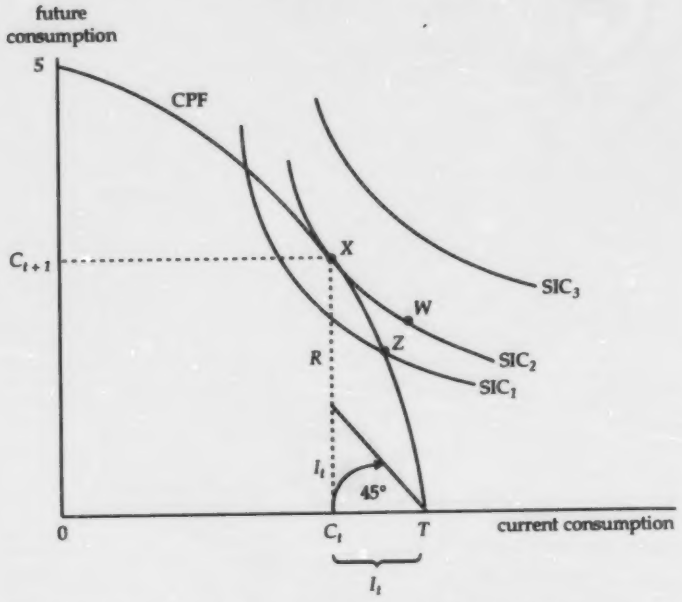
A long controversy surrounds the selection of the appropriate discount rate for evaluating public sector investment projects in practice. However, the choice of this rate is clear under certain theoretical circumstances. Although the real world deviates from these conditions, an understanding of them helps clarify why selecting the social discount rate is difficult and controversial.

We begin with a simple though unrealistic model of the economy of a hypothetical country. We assume that this country does not trade with other counties. Moreover, we initially ignore taxes, risks faced by private sector investors and lenders, and transaction costs associated with making loans; consequently, anyone who wants a loan can borrow the desired amount at the market interest rate. In addition, we ignore market failures, such as externalities and information asymmetry, which could cause private and social discount rates to diverge from one another. Finally, we assume that there are only two time periods: the present, t, and the future, $t + 1$.

This hypothetical economy is depicted in Figure 1. The horizontal axis indicates consumption during the current period and the vertical axis indicates consumption during the future period. The curve labeled CPF is a *consumption possibility frontier*; it repre-

11 Private correspondence with Ken Bayne, City of Vancouver Controller, 1998.

Figure 1: ***Optimal Levels of Consumption and Investment in a Two-Period Model of a Hypothetical Economy***



Note: See text for explanations of the labels and the simplifying assumptions.

sents all the combinations of current and future consumption that are feasible if the economy utilizes its resources efficiently.

Suppose that, at the beginning of the first period, the country has T units worth of resources, which can be allocated between current consumption and investment. There are two extremes. The society could consume all T units in the current period, invest none, and therefore have no future consumption, as represented by point T on the horizontal axis of Figure 1. At the other extreme, the society could consume no units in the current period, invest all T units, and consume S units in the future period. Note that $S > T$, implying a positive rate of return on all resources invested in the current period.

Point X represents a more realistic intermediate position where current consumption equals C_t and future consumption equals C_{t+1}.

At this point, society would relinquish I_t (equals $T - C_t$) units of potential consumption in the current period for investment. But in the future it would consume C_{t+1}, which equals $I_t + R$ units, where I_t represents the amount invested in the first period and R is the return on this investment.

These amounts are expressed graphically in Figure 1. By drawing a 45-degree line from point T, we divide the line between X and C_t, which corresponds to consumption in the future period, into two segments where the lower segment corresponds to I_t and the higher one to R.

Bearing in mind that the model pertains to a country, I_t can be thought of as the sum of a number of smaller investments. The average rate of return on them, r, equals R/I_t. This amount differs from the marginal return on a (small) investment at X. To understand this difference, note that, when viewed from below, the CPF is concave — that is, it bows outward. The implication is that, as the economy moves along the CPF curve from T toward S and more resources are invested in the current period, equal increments in investments engender successively smaller increases in future consumption. In other words, the marginal return on investment falls as investment increases (because the best investments are made first). Consequently, r_X, the marginal rate of return on investment at X, is smaller than r, which is the average rate of return between T and X.[12]

The set of three curves labeled SIC in Figure 1 are *social indifference curves*, which represent preferences for current and future consumption. Each curve represents various combinations of current and future consumption that provide the society with equal levels of satisfaction. For example, the society is indifferent between points X and W on SIC_2; each point produces the same amount of social well-being.

The negative slope of each SIC curve implies that society is willing to give up some units of current consumption only in order

12 By definition, $-(1 + r_X)$ equals the slope of the CPF at X, while its average slope between T and X equals $-C_{t+1}/I_t = -(1 + r)$. Because of the concave shape of the CPF, the slope at X is not as steep as the average slope between X and T. Therefore, $r_X < r$.

to gain more future consumption. Suppose that, to give up one additional unit of current consumption at X, society requires at least $1 + p_X$ units in the future in order to be indifferent. Then the slope of SIC_2 at X is $-(1 + p_X)$. The amount by which the required future amount exceeds one, p_X, is called the *social marginal rate of time preference.*

The shape of the SICs implies that, to forgo a given amount of current consumption willingly, society requires relatively small increases in future consumption when the level of current consumption is high, but larger increases when the level of current consumption is low. For example, SIC_2 is flatter at W than at X, which indicates that, to give up one unit of current consumption at W willingly, society requires less than $1 + p_X$ additional units in the future. In other words, the social marginal rate of time preference is lower at W than at X. Indeed, the social marginal rate of time preference decreases as the level of current consumption increases at every point on each SIC.

Society wants, of course, to reach the highest attainable indifference curve. As can be seen in Figure 1, this curve is SIC_2 given an initial endowment of T units and the CPF. SIC_3 would be even more preferable, but the country's resources are insufficient to reach it. Indeed, the economy can reach SIC_2 only at a single point, X, where SIC_2 and the CPF curve are tangential and their slopes are equal. Consequently, at point X,

$$1 + p_X = 1 + r_X \text{ or } p_X = r_X.$$

Accordingly, if the economy operated at point X, the social marginal rate of time preference would equal the marginal rate of return on investment.

Furthermore, at point X, these rates would equal the economy-wide market rate of interest, denoted by i. As all of these rates would be equal, the choice of SDR would be obvious.

To show why the rate of i would be appropriate, we need to establish first that at X all individuals in society have the same marginal rate of time preference, which equals i, and second that this rate would be the unanimous choice for the SDR.

Suppose that some individuals initially had a marginal rate of time preference greater than i; in effect, they wanted to consume more now. These people could borrow at i, an interest rate below the rate they would actually be willing to pay, and thereby increase their current consumption at the expense of their future consumption. This increase in current consumption would increase the relative value of future consumption, causing their personal marginal rates of time preference to decline until they eventually equaled i. Analogously, individuals with personal marginal rates of time preference initially below i would willingly postpone some current consumption in exchange for increased future consumption. As they did so, their marginal rates of time preference would rise until they equaled i. Thus, at X every individual would have the same marginal rate of time preference, one equal to the economy-wide market rate of interest.

Suppose that a government project would, for example, reduce consumption by \$1 today in order to produce $\$(1 + y)$ in the next period. As every person's marginal rate of time preference equals i, individuals would value resources to be obtained in the next period at $1/(1 + i)$ times their value this period. Thus, everyone would calculate the present value of the project as $\$(1 + y)/(1 + i)$. As all individuals would discount at rate i, it would be the only logical choice for the SDR. This result generalizes to many periods.

Point X is the socially optimal point under the assumptions described above. Later we refer to this point as the first-best outcome. Unlike the hypothetical economy of Figure 1, however, real economies are unable to operate at a point such as X. An actual economy — with taxes, risk, and transaction costs — is more likely to function at point Z.

Later we refer to point Z as the second-best outcome. Here, society would underinvest — actual investment would be less than I_t. The economy could reach only SIC_1, not SIC_2, and the marginal return on investment would exceed the marginal rate of time preference ($r_Z > p_Z$).[13]

13 In Figure 1, the absolute value of the slope of the CPF $(1 + r_Z)$ exceeds the absolute value of the slope of the SIC $(1 + p_Z)$.

Consider the size of the wedge between p_Z and r_Z. Suppose individuals lend $100 to a corporation. Further suppose they have a marginal rate of time preference of 2 percent. Hence, in order to lend $100 to the corporation, they require at least $102 in the future. Assume that the corporation invests the $100 for one period and earns a return of 10 percent, or $10. If the corporate tax rate is 40 percent, then only $106 is available to repay the lenders. If, in addition, the individuals' marginal income tax rate is 50 percent and if they require $1 to cover the transaction cost and risk associated with making the loan, they will net only $2 on this loan. In summary:

gross corporate profit	$10
corporate income tax (40%)	−4
	$6
investors' personal income tax (50%)	−3
investors' transaction cost and risk	−1
investors' return	$2

Hence, the corporation must earn a rate of return of 10 percent for the individuals to receive a return equal to their marginal rate of time preference of 2 percent.

In practice, different individuals and different corporations face different tax rates, and the risk and transaction costs associated with loans vary across investment projects and across individuals. Thus, numerous values exist for both the marginal rate of time preference and the marginal rate of return on investment, and there is no obvious choice for the SDR in the real world.

Alternative Social Discount Rate Candidates

The discussion thus far implies that our problem is a matter of choosing a particular SDR and plugging it into equations (1) or (2). Using this approach, we have five potential SDR candidates: r_Z, p_Z, i, a weighted combination of these three, and s_G, which denotes a rate based on real growth rates.

In fact, we could choose another approach that entails weighting the benefits and costs before discounting them, depending on

whether they change investment or consumption. This approach requires an estimate of a parameter called the *shadow price of capital* (SPC), denoted θ, as well as a discount rate. Furthermore, some economists suggest using a sliding scale of rates that decline as the benefits and costs occur in periods further in the future (see, for example, Harvey 1994; Weitzman 1994; 1998; and Laibson 1997).

Combining these different discount rates and approaches results in eight possible discounting methods:[14]

1. Discount all benefits and costs using r_Z, the marginal rate of return on private sector investments.
2. Discount all benefits and costs using p_Z, the marginal rate of time preference.
3. Discount all benefits and costs using i, the government's real long-term borrowing rate.
4. Discount all benefits and costs using a weighted average of p_Z, r_Z, and i. The weights reflect the amount of the infrastructure project's resources that are financed by consumption, investment, and foreign borrowing, respectively.
5. Discount all benefits and costs using s_G, a rate based on the growth in real per capita consumption.
6. Weight the flows into or out of investment by θ, the shadow price of capital, to convert them to consumption equivalents, and then discount the consumption flows and consumption equivalents using p_Z.
7. Weight the flows into or out of investment by θ to convert them to consumption equivalents, and then discount the consumption flows and consumption equivalents using s_G.
8. Discount using a rate that declines over the time horizon of the project.

14 Throughout the rest of the essay, we continue to use the subscript Z on p and r to emphasize that we are discussing an economy that is at a point such as Z in Figure 1 (rather than at X) and, as a consequence, the marginal rate of time preference is smaller than the marginal rate of return on investment. Furthermore, it reminds us that we require marginal returns, not average returns.

We now discuss these different methods in four subsections. The first pertains to methods 1 through 4, all of which rely on market rates; the next examines method 5. Arrow et al. (1995) refer to the former methods as the *descriptive* approach and the latter method as the *prescriptive* approach. Methods 6 and 7, which are discussed in a third subsection, both require the shadow price of capital. The final subsection examines method 8, the time-declining discount rate method, which can involve either a descriptive or prescriptive approach and has been increasingly proposed for the evaluation of projects with long-term environmental effects.

Each method usually results in a different value for the NPV of the same infrastructure project. Hence, conclusions about whether a specific infrastructure project should be undertaken often depend on the particular social discounting method selected. Thus, choice of method is important.

Descriptive or Market Rates of Interest Approaches

Infrastructure projects use resources that would otherwise be available to the private sector for consumption or investment. Thus, the resources employed have an opportunity cost. Discounting methods that use market rates of interest presume that the resources used for an infrastructure project should return more than they would if they remained in the private sector. If the benefits of a proposed project exceed the opportunity cost of the resources used, it should be undertaken; otherwise, it should not.

To justify the use of market interest rates, analysts usually maintain four assumptions:

- Infrastructure projects compete directly for private sector resources.
- Social preferences (the SICs in Figure 1) correspond to those of a representative individual.[15]

15 This assumption is consistent with giving equal weights to individuals at different points in the income distribution.

- Individual marginal rates of time preference do not vary with the time horizon to which they are applied, and they may be inferred from market observations.
- Only the preferences of currently living individuals matter in making social choices.

Method 1: Using the Marginal Rate of Return on Private Investments, r_Z

In addition to the assumptions listed above, the approach to social discounting that uses r_Z, the marginal rate of return of private investment, also assumes that:

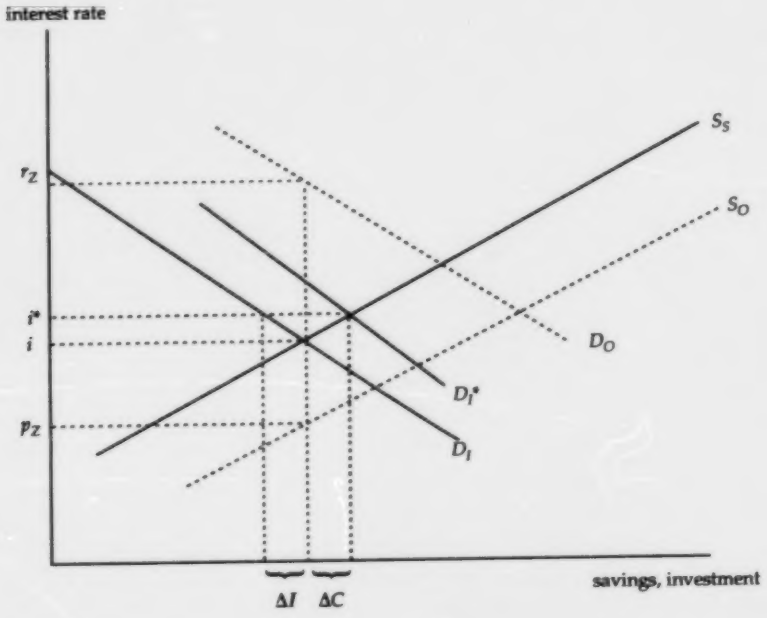
- the infrastructure project is financed entirely by borrowing;
- the economy is closed and does no foreign borrowing; and
- investment is responsive to changes in the interest rate, but the amount of savings is not.

In an influential article, Harberger (1969) makes the most compelling case for the use of r_Z. He analyzes a closed domestic market for investment and savings, such as the one presented in Figure 2. In the absence of taxes and government borrowing, the demand curve for investment funds by private sector borrowers is represented by D_O and the supply curve of funds from lenders (or savers) is represented by S_O.

Now consider the effects of a corporate income tax and a personal income tax. The tax on corporate profits shifts the demand curve down to D_I because part of the returns from investments must now be paid to the government, while the tax on interest income shifts the supply curve up to S_S because part of the interest on savings must now be paid to the government. Thus, as Figure 2 implies, both taxes reduce investment.

Given these taxes, the market-clearing interest rate would be i. That is, investors would pay a rate of i to borrow funds and savers would receive a rate of i prior to paying taxes. However, the marginal rate of return on investment before taxes (that is, the opportunity cost of forgone private sector investment) would be r_Z, with

Figure 2: ***The Effects of Taxes and Government Borrowing on Saving and Investment***



Note: See text for explanations of the labels and the simplifying assumptions.

the gap between r_Z and i representing taxes paid by investors on profits. The marginal return on savings after taxes (that is, the opportunity cost of forgone consumption or, equivalently, the marginal rate of time preference) would be p_Z, with the gap between p_Z and i representing taxes paid by savers on interest income. Note that, as previously discussed, taxes would cause r_Z to exceed p_Z.

Now consider the effects of an infrastructure project. Harberger assumes that it would be financed entirely by borrowing in the closed domestic financial market. Suppose the demand for funds for the new project shifts the market demand curve to D_I^*. The market rate of interest would rise from i to i^*. Private sector investment falls by ΔI and private sector savings increase by ΔC. Since

the increase in private sector savings would exactly equal the decrease in private sector consumption, the infrastructure project would crowd out both investment (by ΔI) and consumption (by ΔC).

Harberger suggests that the social discount rate should be obtained by weighting r_Z and p_Z by the respective size of the relative contributions that I and C would make toward funding the project. That is, he suggests that the social discount rate, s, be computed as follows:

$$s = ar_Z + (1 - a)p_Z, \tag{4}$$

where a equals $\Delta I/(\Delta I + \Delta C)$ and $(1 - a)$ equals $\Delta C/(\Delta I + \Delta C)$.

Finally, Harberger says that savings are not very responsive to changes in interest rates. This assertion, which is strongly supported empirically, implies that the S_S curve is close to vertical and, as a consequence, ΔC is close to zero. (See, for example, Hall 1988 and, more recently, Muellbauer and Lattimore 1995.) The suggestion is that the value of the parameter a is close to one and the value of $(1 - a)$ is close to zero. In other words, almost all of the resources for public sector investment are obtained by crowding out private sector investment. Thus, Harberger suggests that the marginal rate of return on investment, r_Z, is a good approximation of the true social discount rate.

Numerical Values of r_Z. The value of r_Z is, perhaps, best thought of as the rate of return on low-risk private sector investments before taxes but after correcting for inflation.

To compute it, one might start with a market return such as the nominal rate of return on long-term corporate bonds. One possibility in Canada is to use ScotiaMcLeod's monthly Corporate Weighted Long-Term Bond Index, which averaged 6.97 percent in 1997.[16] This value must, however, be adjusted to account for taxes and anticipated inflation. For manufacturing sectors, the marginal combined federal and provincial corporate income tax rate as of

16 The index is composed of bonds with maturities in excess of 15 years (Statistics Canada, CANSIM database).

January 1997 was 38.6 percent in British Columbia and 35.6 percent in Ontario, while the median for all ten provinces was 37.6 percent. For nonmanufacturing sectors, it was 45.6 percent in British Columbia and 44.6 percent in Ontario, and the all-province median was 45.1 percent (KPMG website: www.kpmg.ca). These estimates suggest that 40 percent is a reasonable overall corporate tax rate.[17] The implication is a nominal pre-tax return on bonds of [0.0697/(1 – 0.40)], or 11.62 percent. Using 1.6 percent, the percentage change in the CPI (all items) in 1997, as the expected rate of inflation,[18] gives a real expected pre-tax rate of return on investment of [(0.1162 – 0.016)/(1 + 0.016)], or 9.9 percent.[19] Rounding to the nearest whole number gives an SDR of 10 percent.

To illustrate discounting with r_Z, we return to the pedestrian overpass example (the annual net benefits listed in Table 1) and use a discount rate of 10 percent:

17 A detailed study by Shoven and Topper (1992) of the cost of capital in Canada, the United States, and Japan also suggests the use of a 40 percent overall corporate tax rate.

18 As previously discussed, the CPI figures overestimate the general increase in consumer prices by about 0.7 percent. Using an inflation rate seven-tenths of one percentage point lower than before would yield an estimate of r_Z that is approximately 0.7 of a percentage point higher than before. The same caveat applies to the calculation of all real returns and growth rates that follow.

19 Using historical data on the average return on Canadian long-term corporate bonds yields different estimates of the appropriate discount rate depending on the period chosen. For the 1950–87 period, Hatch and White (1988) estimate the (geometric) average return to McLeod-Weir's index of corporate bonds (industrials) to be 5.56 percent. Using a 40 percent marginal corporate income tax rate and adjusting for inflation, which averaged 4.71 percent during this period, yields a real pre-tax rate of return of 4.35 percent. In contrast, the ScotiaMcLeod long-term index for the 1977–97 period yields an arithmetic average of annual returns of 10.82 percent. Using a 40 percent tax rate and adjusting for CPI inflation, which averaged 5.3 percent over this period, yields a pre-tax real return of 12.1 percent. (Statistics Canada, CANSIM database.)

Using the average annual return of the ScotiaMcLeod weighted long-term corporates (1978–97) combined with the McLeod-Weir industrials series (1948–77) yields an average nominal return of 8.2 percent. With a tax rate of 40 percent and average inflation over the whole period (1948–97) of 4.5 percent, the real pre-tax return was 8.8 percent.

$$NPV = -\$405{,}000 + \$100{,}000/(1 + 0.1)^1 + \$100{,}000/(1 + 0.1)^2 + \$100{,}000/(1 + 0.1)^3 + \$100{,}000/(1 + 0.1)^4 + \$100{,}000/(1 + 0.1)^5 - \$30{,}000/(1 + 0.1)^5 = -\$44{,}549.$$

Using this method, the NPV is negative. Because r_Z is almost always the largest value of the SDR, its use tends to be favored by those who would like to minimize the role of infrastructure and other government investments (Boardman, Vining, and Waters 1993).

Criticisms of the Calculation and Use of r_Z. Several factors suggest that use of an SDR of 10 percent is too high. Some of these criticisms pertain to the estimation of r_Z, while others pertain to the strong assumptions made by Harberger (1969). First, private sector rates of return may be pushed upward by distortions caused by negative externalities and monopolistic pricing. Second, the return on investment incorporates a risk premium, but public infrastructure projects may be less risky than private sector investments.[20] Third, the project may be financed by taxes, rather than by loans, in which case C is more likely than I to be crowded out; the reason is that most taxes are collected from individuals through income, payroll, and consumption taxes, which mainly affect consumption, especially if savings rates are fairly low. Fourth, the project may be partially financed by loans obtained from foreigners. Fifth, there may not be a fixed pool of investment such that government investment replaces private investment dollar for dollar. Indeed, one can imagine cases in which a government infrastructure project (a road, bridge, airport, or railway) actually creates private investment opportunities, raising the private return to capital. If the economy

20 Arrow and Lind (1970) argue that government can improve on the social allocation of risks by holding a broader portfolio of assets than can any private agent. Because of the greater diversification of its portfolio, government pays a lower interest rate than does the private sector, reflecting its lower risk. The lower rate is the appropriate one to use in discounting public investments. The counterargument is that government pays a lower rate on its debt because it alone enjoys the coercive power of taxation and high-powered money creation, thus guaranteeing that it can always dispense with its nominal debt obligations.

is not fully employing all its resources, then complete crowding out is unlikely.

For these reasons, r_Z should probably be viewed as the upper limit of the SDR. Given the evidence shown above in calculating the real expected pre-tax rate of return on investment, the implication is a maximum value of 10 percent.

Method 2: Using the Marginal Rate of Time Preference, p_Z

In addition to the general assumptions underlying the descriptive approach, the marginal rate of time preference method also assumes that

- the economy is closed and does no foreign borrowing; and
- the government project is tax financed, and taxes chiefly reduce consumption.

The appeal of using p_Z as the SDR is that it represents, in principle, the rate at which individuals in society are willing to postpone a small amount of current consumption in exchange for additional future consumption (and vice versa).

If the infrastructure project is financed entirely by domestic taxes and if taxes reduce consumption but not investment, it is appropriate to set a equal to zero in equation (4), yielding an SDR equal to p_Z.

Numerical Values of p_Z. In practice, the best return many people can earn in exchange for postponing consumption is the real after-tax return on savings. Therefore, we use this rate as an estimate of p_Z.

To compute it, one can start with the interest rate on government bonds. For example, the average monthly yield on Canadian long-term government bonds with maturities over ten years in 1997 was 6.68 percent. This nominal pre-tax rate of return on savings must, however, be converted to a real after-tax rate by adjusting for taxes and inflation. Shoven and Topper (1992) suggest using a tax rate for individual savers of 45 percent. The implication is that the after-tax yield on long-term bonds is $(1 - 0.45) \times (0.0668)$, which

is 3.67 percent. Again using the actual percentage change in the CPI (all items) for 1997 of 1.6 percent as the expected rate of inflation, we obtain a real after-tax yield of (0.0367 – 0.016)/(1 + 0.016), or 2 percent.[21] Calculations of this sort generally produce estimates of the marginal rate of time preference that range from just below zero to 4 percent.[22] Thus, we suggest p_Z equals 2 percent with sensitivity analysis at zero and 4 percent.

To illustrate discounting with p_Z, we return to the pedestrian overpass example (the annual net benefits of Table 1) and use a discount rate of 2 percent:

$$\begin{aligned}\text{NPV} = &-\$405{,}000 + \$100{,}000/(1 + 0.02)^1 + \$100{,}000/(1 + 0.02)^2 \\ &+ \$100{,}000/(1 + 0.02)^3 + \$100{,}000/(1 + 0.02)^4 + \$100{,}000 \\ &/(1 + 0.02)^5 - \$30{,}000/(1 + 0.02)^5 = \$39{,}174.\end{aligned}$$

Using $p_Z = 0.02$ to discount all benefits and costs implies the project should proceed. Because p_Z is one of the smallest values of the SDR, its use tends to be favored by those who support infrastruc-

21 Since high-income individuals do most of the personal saving, the rates they face are likely to be the most appropriate ones to use. As of March 1998, the combined federal and provincial marginal tax rate for high-income individuals was 54.2 percent in British Columbia and 50.9 percent in Ontario, with a median rate for all ten provinces of 50.35 percent (www.kpmg.ca). Using this tax rate and adjusting for inflation as before yields a slightly lower estimate for p_Z of 1.69 percent.

22 Using historical data on the average return on Canadian long-term government bonds yields a lower estimate for p_Z. For the 1950–87 period, Hatch and White (1988) estimate the (geometric) average return on long-term government bonds to be 5.22 percent. Using a 45 percent marginal income tax rate yields an after-tax nominal return of [0.0522 (1 – 0.45)], or 2.87 percent. Inflation averaged 4.71 percent during that period, so the real post-tax return averaged –1.8 percent. It is important to bear in mind that these are *ex post*, not *ex ante*, estimates. While the *ex post* real returns may be negative, it is very likely that *ex ante* real returns are positive, otherwise few people would purchase government bonds. Either way, as we believe that the marginal rate of time preference is positive, we rule out negative real discount rates. The average annual yield on a long-term government bond over the 1936–97 period was 6.41 percent. With a marginal tax rate of 45 percent and average inflation of 4.2 percent, the average post-tax real return over this period was –1 percent. (Statistics Canada, CANSIM database; and Leacy 1983.)

ture and other government investment projects (Boardman, Vining, and Waters 1993).

Criticisms of the Calculation and Use of p_Z. Several criticisms pertain to the computation and use of p_Z. First, individuals differ in preferences and opportunities; while some are saving, others are borrowing. At the margin, some save, in effect, by reducing their debt. Because consumer borrowing rates exceed savings rates and because reducing debt is not taxed, consumers who save by reducing their debt earn a much higher real after-tax return than savers who earn a real after-tax return of 2 percent. Between 1973 and 1998, the real average annual interest rate on five-year mortgages was 5.4 percent (Statistics Canada, CANSIM database). Therefore, high-income individuals who saved by paying down their mortgages earned a real after-tax average annual return of 5.4 percent.[23] It is not obvious how to aggregate these various rates of interest into a single marginal rate of time preference.

Second, many individuals simultaneously pay down mortgages, buy government and corporate bonds as well as stocks for retirement, and sometimes even borrow on their credit cards at very high interest rates (see the discussion in Lind 1990). Given this mixed behavior, it is unclear how individual consumers can be said to be equating their marginal rates of time preference with a single market rate of interest.[24]

Third, market rates of interest reflect the rates of time preference of individuals currently alive. Some economists argue that these individuals fail to account appropriately for the effects of long-term infrastructure projects on the welfare of future generations (Ramsey 1928; Eckstein 1958; Phelps 1961; Marglin 1963; Arrow et al. 1995, 136).

23 Those who paid down the balance on their credit cards would have earned even more!

24 Laibson (1997) argues, however, that individuals who use time-declining discount rates may have precommitted themselves to saving a certain amount of their income in an illiquid asset while simultaneously borrowing for current consumption from ready sources of credit. (See the discussion in the subsection about method 8.)

Method 3: Using the Government's Real Long-Term Borrowing Rate, *i*

In addition to the general assumptions underlying the descriptive approach, the method of discounting that uses the government's real long-term borrowing rate, *i*, also assumes that

- the proposed infrastructure project is funded completely from borrowing from abroad; and
- the real interest rate at which the government can borrow, *i*, does not change when it increases its debt because financial capital is completely mobile internationally, and Canada is too small to affect the single equilibrium world rate of interest.

Suppose an infrastructure project can be financed at a rate of *i* and has a rate of return of *y*. If *y* exceeds *i* and all the funds are borrowed from abroad, then it is possible to achieve an actual Pareto improvement for society — a situation in which some people are better off and no one is worse off — if the government can tax the beneficiaries in order to raise the funds needed to pay back its foreign debt.

Numerical Values of i. In 1997, the average annual return to Canadian long-term government bonds was 6.68 percent and the CPI inflation rate was 1.6 percent, giving an average real long-term government bond rate of 5 percent.[25] Using this discount rate, the pedestrian overpass example has an NPV of $4,442. This NPV is between the NPVs calculated at the other rates because, as indicated in Figure 2, the government borrowing rate lies between the marginal rate of time preference, p_Z, and the private return on investment, r_Z.

25 Again, the use of historical averages results in different rates. Data from Hatch and White (1988) for the 1950–87 period indicate that the average real Canadian government rate was 0.5 percent. Averages from the 1936–97 period obtained from Statistics Canada's CANSIM database and Leacy (1983) indicate that the real long-term government rate was 2.1 percent.

Criticisms of the Calculation and Use of i. One criticism of this approach is that a project could produce an actual Pareto improvement only if the beneficiaries alone paid the taxes needed to retire the government loan — an unlikely situation especially if the project benefits are nonmarket goods or services.[26] Some funding inevitably would come at the expense of the consumption or investment of others.

The other major criticism is that Canada is probably unable to borrow or lend at an unchanging real interest rate. This empirical issue is not completely resolved, and more evidence is needed on the extent to which the international borrowing rate rises when government increases its borrowing and the extent to which this crowds out consumption, investment, and net exports. Helliwell (1998, ch. 4) provides the most recent and appropriate information. He estimates that a 1 percent increase in domestic Canadian savings rates (the ratio of private savings to GDP) raises the Canadian investment-to-GDP ratio by 0.3 percent. But if capital were perfectly mobile internationally, interest rates in Canada would not change and the increased savings would be absorbed outside the country. Thus, Helliwell concludes that financial capital is imperfectly mobile between Canada and the rest of the world. Consequently, an increase in government borrowing in Canada is likely to raise domestic real interest rates and crowd out a bit of consumption, some investment, and net exports.

Method 4: Using the Weighted Social Opportunity Cost

Proponents of the use of r_Z assume that resources for government investment come from borrowing that crowds out domestic invest-

26 Given social attitudes toward income distribution, however, one might argue that the project should proceed as long as the beneficiaries as a class are no wealthier than those taxed to repay the government loan. In this as in other cases, one must make explicit value judgments regarding the distribution of income before suggesting that a project should go forward. In other words, efficiency considerations can rarely be separated cleanly from distributional issues.

ment dollar for dollar. Advocates of the use of p_Z assume that resources come from taxes that crowd out current domestic consumption dollar for dollar. Lind (1990) and others argue that foreign borrowing is another potential source of resources. Thus, a government project need not crowd out domestic private consumption or investment dollar for dollar.[27] If a is the proportion of the infrastructure project's resources that displace private domestic investment, b is the proportion financed by borrowing from foreigners, and $1 - a - b$ is the proportion that displaces domestic consumption, then this method computes the social discount rate as these rates' weighted average, which is called the weighted social opportunity cost of capital (WSOC):

$$\text{WSOC} = ar_Z + bi + (1 - a - b)p_Z . \tag{5}$$

As $p_Z < i < r_Z$, it follows that $p_Z < \text{WSOC} < r_Z$. Obviously, methods 1, 2, and 3 are special cases of this more general approach.

Numerical Values of the WSOC. As mentioned earlier, the Treasury Board Secretariat (Canada 1976) recommends the use of a 10 percent real social discount rate, with sensitivity analysis at plus or minus 5 percentage points. The rationale for this rate draws extensively on Jenkins (1973; 1977), who assumes that the funds come from borrowing and estimates a at 0.75, b at 0.20, and $1 - a - b$ at 0.05. Subsequently, he has reaffirmed these estimates (Jenkins 1981). Using his weights and our point estimates from 1997 of r_Z at 10 percent, i at 5 percent, and p_Z at 2 percent gives the real WSOC as 8.6 percent.[28]

27 Under a flexible exchange rate regime, net exports may be reduced when increased government borrowing raises Canadian interest rates relative to those abroad, causing a financial capital inflow and an appreciation of the exchange rate.

28 Using estimates of r_Z equals 4.35 percent, p_Z equals –1.8 percent, and i equals 0.5 percent (based on the Hatch and White [1988] data for the 1950–87 period), and Jenkins' weights gives a real WSOC of 3.3 percent. Constraining p_Z to be nonnegative gives the WSOC as 3.4 percent. Using our previously calculated...

Burgess (1981, 385–392) discusses the source of Jenkins' estimated weights and suggests that the parameter a is more likely to be in the range of 26 to 32 percent, b in the range of 55 to 64 percent, and $1 - a - b$ in the range of 10 to 13 percent. These estimates are based on an interest elasticity of the supply of foreign funding in the range of 7 to 10. Using an interest elasticity of 7, which gives a equals 0.32 and b equals 0.55, and our point estimates of r_Z, p_Z, and i from 1997 yields a WSOC of 6.6 percent. The NPV of the pedestrian overpass example using an SDR of 6.6 percent is –$12,350, an amount between that obtained using method 1 and method 2. When using the WSOC method and assuming that funds come from borrowing, we suggest performing sensitivity analysis on the WSOC at 5.0 and 7.7 percent, which correspond, respectively, to an elasticity of the supply of foreign funding of infinity (financial capital is perfectly mobile internationally) and of 2.

Suppose the project is financed by taxes, rather than by issuing debt to domestic or foreign lenders; then b equals zero. The parameter a should reflect the portion of taxes that reduces investment, while $1 - a - b$ should reflect the portion of taxes that reduces consumption. A crude approximation for a is provided by the ratio of gross investment to GDP. For 1997, this ratio equaled 16.6 percent, which leads to an estimate of the WSOC as 3.3 percent.[29] We suggest performing sensitivity analysis with the WSOC equal to 0.7 percent (corresponding to r_Z of 4.4 percent and p_Z of zero, our lower

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Note 28 - cont'd.

...averages of r_Z equals 8.8 percent (from 1948–97), p_Z equals –1 percent (from 1936–97), and i equals 2.1 percent (given an average long-term government bond yield of 6.41 percent and inflation of 4.2 percent between 1936 and 1997), and Jenkins' weights gives a real WSOC of 7 percent. Constraining p_Z to equal zero, the WSOC is 7.02 percent.

29 WSOC = (0.166 × 10%) + (0.834 × 2%) = 3.3%. The average of the ratio of business gross fixed capital formation to GDP (both at market prices) for the four quarters of 1997 equals 16.6 percent. Averaging this quarterly data for the 1961–97 period yields a value of 13.8 percent. An alternative measure, the percentage distribution of GDP by expenditure category (business investment: fixed capital), averaged 16.25 percent between 1926 and 1995. (Statistics Canada, CANSIM database.)

historical estimates) and 5.3 percent (corresponding to r_Z of 12.1 percent and p_Z of 4 percent, our upper historical estimates).

Criticisms of the Calculation and Use of the WSOC. Most of the criticisms pertaining to the calculation and applicability of r_Z, i, and p_Z also apply to this method.

The Prescriptive Approach

Long-lived infrastructure projects typically involve a sacrifice of consumption by the current generation in order to generate net benefits for the current and future generations. To decide whether the sacrifice is warranted, society must weight the current loss in consumption against the future gains. Market interest rates are one possible source of those weights. Advocates of the prescriptive approach suggest an alternative.

Method 5: Using the Real Growth Rate, s_G

Proponents of social discounting based on the real growth rate maintain that market interest rates are inappropriate sources of such weights because they reflect the preferences of individuals in the current generation and do not adequately account for the welfare of future generations, and because an economy using market rates will invest too little compared to the socially optimal amount for the reasons discussed above.[30] Instead, they argue, society should treat all generations' welfare equally but should recognize that, with ongoing economic growth, future generations will likely have higher per capita consumption than does the current generation and, therefore, consumption by a future generation should have a lower weight. Specifically, the rate at which the weights decline across generations should be proportional to the growth rate of per capita consumption: the higher the growth rate, the

30 In Figure 1, the distorted economy is operating at point Z, with less investment than at the "first-best" point X.

higher the SDR. (See Ramsey 1928; Phelps 1961; Marglin 1963; and, for an intuitive explanation, Brent 1994, ch. 9.)

To justify the prescriptive approach, proponents usually maintain three assumptions:

- In social evaluations, every future generation's welfare should be treated the same as the current generation's welfare.
- Long-lived infrastructure projects involve transfers of consumption among generations.
- Society should discount the consumption flows to and from a future generation relative to those to and from the current generation because the future generation will have higher per capita consumption due to the long-run trend of economic growth, and because the social value of an extra unit of consumption falls as the level of consumption rises (the diminishing social marginal utility of consumption).

The prescriptive approach denotes the SDR as s_G and sets it equal to the long-run rate of growth in per capita consumption, g, multiplied by a constant, e, which is an elasticity that measures how fast the social marginal utility of consumption falls as per capita consumption rises:

$$s_G = ge .$$

Industrialized market economies have seen periods, some lasting as long as a decade or more, during which per capita consumption has declined. The overwhelming experience since the Industrial Revolution, however, has been that average consumption rises over the long run; thus $g > 0$ and $s_G \geq 0$.

The parameter e ($0 \leq e < \infty$) represents the social evaluation of the intergenerational distribution of income. It summarizes the key value judgment about how quickly the marginal utility of consumption declines as average consumption rises. When e equals 1, the relative weight on each generation's consumption is the inverse of its relative consumption per capita. The implication is that a 10 percent reduction in the consumption of the current generation (for example, from $20,000 to $18,000) is an acceptable tradeoff for

a 10 percent increase in the consumption of a richer future generation (for example, from $40,000 to $44,000). In other words, society weights the poorer current generation's loss of each dollar of consumption as twice as important as a dollar's gain to the richer future generation because the latter (initially) has twice as much per capita consumption.

Setting e equal to zero means that there should be no discounting; society should treat each unit of consumption received by future richer generations as identical to a unit of consumption by the present generation. Hence, a zero value for e signifies a complete lack of concern for intergenerational inequality in per capita consumption. At the opposite extreme, an infinite e indicates that society cares only about the worst-off current generation and never sacrifices current consumption to increase the consumption of future generations.

If society wishes to give more weight to the current generation, it can add a pure rate of time preference, d, to the product of g and e:

$$s_G = ge + d\,, \tag{6}$$

where d represents the rate at which society discounts future generations' welfare, even if all generations have equal consumption per capita (that is, g equals zero). Assigning a positive value to d has been debated. Ramsey (1928) argued that this approach is ethically indefensible. Arrow (1995) shows, however, that although the presumption that all generations' welfare should be weighted equally seems reasonable, it can result in requiring excessively high rates of savings from the current (or even every) generation. He demonstrates that, under reasonable parameter values, the current generation could be required to save approximately two-thirds of its income! To avoid this result, a positive pure rate of time preference should be employed in using method 5. Arrow tentatively suggests a figure of about 1 percent for d, which is the value we use in our calculations below.

Numerical Values of s_G. Kula (1984) calculates s_G for Canada. He estimates the average growth rate between 1946 and 1975 was 2.8 per-

cent.[31] He treats e as representing the preferences of an average individual and estimates it from an aggregate demand equation for food, arriving at a figure of 1.56.[32] Finally, he views d as representing the average individual's expected annual mortality rate, which he estimates is 0.8 percent per year.[33] Consequently, he estimates:

$$s_G = (0.028)(1.56) + 0.008 = 5.2\% .$$

We believe, however, that Kula's estimate is a bit high. First, we update and refine his estimated growth rate. Using data from 1926 to 1995 gives an estimated Canadian growth rate, g, of 2.23 percent per annum.[34] Second, we modify e. Brent (1994) suggests that e should be between 0 and 1, with 0.5 as a benchmark. Arrow et al. (1995) argue that individuals reveal their own values for e through their behavior with respect to risk and intertemporal choice. They survey studies that indicate individual elasticities of marginal utility of consumption lie between 1 and 2. Thus, estimates of e vary between 0 and 2, with some consensus that setting e equal to 1 would not be unreasonable. With our estimate of g at 2.2 percent, e at 1, and, following Arrow (1995), d as 1 percent, then s_G equals

31 The average growth rate in consumption is the coefficient of time in a simple linear regression of the natural logarithm of real per capita aggregate consumption on time.

32 Kula's approach to estimating e is based on an additively separable utility function in food and nonfood. The elasticity of the marginal utility of consumption is measured by the ratio of income elasticity to the compensated price elasticity of the food demand equation. He estimates the latter using aggregate annual data for Canada from 1954 through 1976 on food per adult equivalent, income per adult equivalent, and the ratio of price indices for food and nonfood. (For details, see Kula 1984, 874–876.)

33 Kula's idea is that the average individual is chosen at random, and so should have the average death rate of the population as a whole.

34 Using Statistics Canada CANSIM data from 1926 to 1995, we estimated the following model (t-statistics in parentheses):

$$\ln(\text{real consumption expenditure/population}) = \underset{(289.8)}{7.4} + \underset{(55.9)}{0.0223} \times \text{time}; \; R^2 = 0.98$$

3.2 percent.[35] Sensitivity analysis with e ranging between 0.5 and 1.6 implies s_G ranges from 2.1 to 4.6 percent.

Criticisms of the Calculation and Use of s_G. There are several criticisms of this approach and of the particular estimated values. First, the estimate of g may be inaccurate. We estimate the growth rate in real (aggregate) consumption expenditure per person using the national income accounts, which may not accurately measure what economists mean by consumption. For example, this consumption measure includes purchases of consumer durables, which most analysts believe should be interpreted as investment. Also, it does not include the quantity and quality of public goods, which certainly affect consumers' welfare.

An alternative approach is to measure g as the average rate of growth of real per capita GDP. This method is plausible because GDP includes both private sector consumption and goods produced in the public sector. We estimate that using this measure yields an average growth rate of 2.54 percent per annum in Canada during the 1926–95 period.[36]

Using this growth rate and e equals d equals 1 percent gives s_G equal to 3.5 percent. But, as GDP includes investment and net exports as well as consumption, we prefer our previous estimate.

Second, the parameter e relies on a social value judgment about intergenerational equality. It may be even more difficult to aggregate

35 If one wished to follow Kula's approach of proxying the pure rate of time preference by the annual death rate, which equals 0.7 percent in the 1996 census, then s_G would equal 2.9 percent.

36 The estimated model (t-statistics in parentheses) is:

$$\ln(\text{real GDP/population}) = 7.05 + 0.0254 \times \text{time}; \; R^2 = 0.96$$
$$(196.2)\ (41.5)$$

In fact, the measured growth rate slowed significantly after 1972. Regressions of the log of real per capita GDP on time yield g estimates of 2.55 percent for 1926–72, but only 1.58 percent for 1973–95. An F test rejects the hypothesis that these two coefficients are the same. On the other hand, an F test does not reject the hypothesis that the growth rate (the coefficient of time) was the same before and after 1972 in the real consumption per capita regression (see footnote 34). This implies the trend line in growth did not change.

individual preferences about equality than to aggregate individual rates of time preference.

Third, the recent historical growth rate may be a poor predictor of the future growth rate, g. If a future generation is poorer than the present one, then this method would imply the use of a negative discount rate.

The final criticism, which also applies to the marginal rate of time preference method, refers back to Harberger's argument (1969). If s_G is less than r_Z, this indicates that society is underinvesting (at point Z in Figure 1) relative to the socially best outcome (point X). If a government investment produces a one-period real return of y greater than s_G, society should make this investment because it improves social welfare according to the explicit value judgments used in calculating s_G. However, if r_Z exceeds y, social welfare would improve even more if private investment, rather than the government investment, increased. The shadow price of capital approach (described in the following subsection) provides a solution to the problem.

The Shadow Price of Capital Approach

If all the resources invested in an infrastructure project displace current consumption and all the benefits produce additions to future consumption, then the SDR should reflect social choices in trading present for future consumption. Thus, the choice narrows to p_Z or s_G. However, any proposed project could produce costs and benefits in the form of consumption or investment. Due to market distortions, the rate at which individuals are willing to trade present for future consumption, p_Z, differs from the rate of return on private investment, r_Z (as discussed at the beginning of this section). Thus, flows of investment and flows of consumption should be treated differently.

Methods 6 and 7: Using the SPC and p_Z or s_G

The shadow price of capital (SPC) methods convert investment gains or losses into consumption equivalents, which, like consumption flows themselves, are then discounted at p_Z or s_G.

The SPC approach assumes that:

- Due to capital market imperfections, the first-best amount of investment and saving is not feasible, and society operates at Z in Figure 1 where the return on investment, r_Z, exceeds the return on deferred consumption, p_Z.
- Private investment should be weighted by the SPC, which equals the present value of the future stream of consumption resulting from that investment (discounted at the SDR).
- Because the SDR measures the value of a marginal increase in consumption in the future versus a marginal decrease in consumption in the present, it should be used to discount flows of consumption in infrastructure analysis. The SDR can be the marginal rate of time preference of a representative living individual, p_Z, or the rate obtained using the real growth rate, s_G.

This approach was first suggested by Eckstein (1958) and systematically developed by Bradford (1975). It has a strong theoretical appeal but is difficult to use in practice. Consequently, despite a growing consensus that it is, in principle, the best approach, there are few examples of its actually being used to evaluate infrastructure or other public sector projects.

The SPC method requires that discounting be done in four steps. First, the costs and benefits in each period are divided into those that directly affect consumption and those that directly affect investment. Second, flows into and out of investment are multiplied by the SPC, denoted by θ, to convert them into their consumption equivalents. The value of θ, which is explained below, is generally thought to lie between 1.5 and 2.5. Third, changes in consumption are added to changes to the consumption equivalents of the investment flows. Fourth, the resultant flows are discounted at the SDR, which measures how society values the cost of postponing consumption. Given this framework and the related assumptions, p_Z or s_G are the only appropriate values for the SDR.

Consumption and investment are treated differently because resources that go into consumption are used up during the period in question, while those that go into investment generate a stream of consumption benefits in future periods. To see this point, sup-

pose a dollar is invested for a number of periods, and during each subsequent period, the returns on the investment are consumed. Thus, displacing a dollar of private sector investment results in a lost stream of future consumption. In contrast, displacing a dollar of private sector consumption results in the loss of only a dollar of consumption during a single period.

Now let us consider how to value the lost consumption that results from a dollar of displaced private investment. We initially make some restrictive, simplifying assumptions but relax them later. Suppose that each dollar invested in the private sector earns a return of r_Z during each period. Assume that all of the r_Z is consumed at the end of the period in which it is generated, and the original dollar is reinvested. Thus, r_Z is consumed each period in perpetuity. To obtain the present value of this consumption stream, we discount the amounts received each period at the SDR, which is denoted by s. Using the formula for the present value of a perpetuity, we obtain:

$$\theta = r_Z/s, \tag{7}$$

where s equals p_Z or s_C. The parameter θ is called the shadow price of capital. It represents the present value of the consumption resulting from investing one dollar in the private sector (under the above assumptions). By multiplying flows into and out of private sector investment by θ, we convert them into their consumption equivalents. Because r_Z is almost always greater than p_Z or s_C, the value of θ generally exceeds 1. Thus, displaced investment is more costly to society than displaced consumption.[37]

To explore the shadow price approach a bit further, suppose that the government is evaluating an infrastructure project that would yield real annual benefits of B per year indefinitely. If all of these benefits were consumed each year as they arose, then the present value of this perpetual consumption flow discounted at s would be B/s.

37 Note that increments to investment are treated the same as displaced investments — they are also multiplied by θ. Thus, flows to investment are more beneficial than flows of consumption.

Now consider two extreme cases. If all the capital cost of the project, K, were paid in year 0 and all these funds were raised from forgone consumption, then the rule would be to undertake the project if B/s exceeded K. In this extreme situation, the SPC methods give a result identical to that of method 2, which discounts the flows at the marginal rate of time preference (s equals p_Z) or method 5, which discounts on the basis of real growth rates (s equals s_G).

For the opposite extreme, suppose that all the funds would be raised from private investment. In this situation, under the SPC method, the rule would be to undertake the project if B/s exceeded θK, which equals $(r_Z/s)K$, or, equivalently, if B/r_Z was greater than K. Thus, future net benefits would be discounted at the marginal rate of return on private investments, which is what Harberger (1969) suggests (method 1).

Both of these cases represent unlikely extremes where the infrastructure project crowds out either private consumption or private investment dollar for dollar. In other words, as suggested previously, p_Z and r_Z are best viewed as extreme lower and upper limits for the SDR.

One reason that the SDR reduces to r_Z in the second extreme case is that the expression for the SPC in equation (7) embodies several simplifying assumptions. One is that the infrastructure does not depreciate. Another is that the entire return from the investment is consumed during the period in which it occurred. It seems more likely, however, that some of the return from the investment would have been consumed and some of it would have been reinvested. Consideration of these possibilities leads to a more general expression for the SPC:

$$\theta = \frac{(r_Z + \delta)(1-f)}{s - r_Z f + \delta(1-f)}, \tag{8}$$

where r_Z is the net return on capital after depreciation, δ is the depreciation rate of capital, f is the fraction of the gross return that is reinvested, and s is the social discount rate. Note that, in the absence of depreciation and reinvestment — that is, if δ and f are both zero — then this formula reduces to our initial SPC expression: $\theta = r_Z/s$. (The derivation of equation (8) is found in Appendix A.)

Numerical Values of the SPC. To apply equation (8), we need values for f and δ. The gross investment rate — that is, the ratio of gross investment to GDP — can be used as a rough measure of f. In discussing method 4, we estimated this rate at 16.6 percent, based on 1997 data for Canada. To obtain a value for δ, the depreciation rate, we rely on US estimates obtained by Hulten and Wykoff (1981). They find that the annual depreciation rate for equipment used in manufacturing is 13.3 percent and the annual depreciation rate for structures used in manufacturing is 3.4 percent. Weighting these rates by the relative proportions of equipment (67 percent) and structures (33 percent) in the US capital stock (United States 1990) gives an average annual depreciation rate of ($0.67 \times 0.133 + 0.33 \times 0.034$), or 10 percent.

Using r_Z and δ each equal to 10 percent, f equal to 16.6 percent, and s equal to p_Z at 2 percent yields a value for the SPC of 1.92, implying that $1.00 of private sector investment would produce a stream of consumption benefits with a present value equal to $1.92. Thus, any public sector project that would increase private sector investment by $1.00 would produce consumption benefits equal to $1.92, while any public sector project that would displace private sector investment by $1.00 would have an opportunity cost of $1.92. Performing sensitivity analysis yields estimates of θ equal to 2.5 with s equal to p_Z at 0 percent and θ equals 1.56 with s equal to p_Z at 4 percent. As one can see from equation (8), a low value for s implies a high value for θ and vice versa.

Alternatively, we could use s_G instead of p_Z as the estimate of the SDR. With our point estimate for s equal to s_G at 3.2 percent, we get θ equal to 1.69. With s equal to s_G at 2.1 percent and 4.6 percent, the recommended bounds of θ for sensitivity analysis are 1.9 and 1.48, respectively.[38]

To illustrate how to use the SPC approach in practice, we can again use the pedestrian overpass example. Because the net present value with the shadow price method depends on the specifics

38 Long-term historical averages give slightly different estimates. Using our 1948–97 average for r_Z of 8.8 percent (see footnote 19), s_G of 3.2 percent, and the 1926–95 average for f of 16.25 percent (footnote 29), and assuming a 10 percent depreciation rate, then θ equals 1.55.

Table 3: ***Computing the NPV of the Pedestrian Overpass Using the Shadow Price of Capital Method***

	Changes in Private Sector Investment (1)	Changes in Consumption (2)	Changes in Investment × θ (3)	Total Changes in Consumption (4) = (2) + (3)
		(dollars)		
		Initial Outlay Paid Directly Out of Taxes		
Year 0	–67,230	–337,770	–129,082	–466,852
Year 1	1,660	98,340	3,187	101,527
Year 2	1,660	98,340	3,187	101,527
Year 3	1,660	98,340	3,187	101,527
Year 4	1,660	98,340	3,187	101,527
Year 5	–3,320	73,320	–6,374	66,946
NPV (s = 2%)				–19,630
		Funds Raised through Issuing Bonds		
Year 0	–405,000	0	–777,600	–777,660
Year 1	62,788	37,212	120,553	157,765
Year 2	65,844	34,156	126,420	160,576
Year 3	69,052	30,947	132,580	163,527
Year 4	72,423	27,577	139,052	166,629
Year 5	70,980	–980	136,282	135,302
NPV (s = 2%)				–38,006

of project funding, we compute it under two alternative funding arrangements. We first assume that the $405,000 initial cost outlay would be paid out of tax revenues collected at the beginning of the project. Our result is an NPV of –$19,630. We then assume the $405,000 would be funded by municipal bonds paid for by local residents at 5 percent real interest through five equal annual installments of $93,544.79. The NPV in this case is –$38,006. The key parts of these analyses are summarized in Table 3.

Consider the case in which the $405,000 initial cost outlay would be paid out of tax revenues. The first step in applying the SFC method is to determine the proportion of each benefit and cost that

should be allocated to investment and the proportion that should be allocated to consumption. Suppose that 16.6 percent of the $405,000 in taxes required to pay the initial cost outlay of $67,230 would displace private sector investment, while the remaining $337,770 would displace consumption.[39] Similarly, suppose that the $50,000 annual costs also result in increased taxes with 16.6 percent, or $8,300, displacing private sector investment and 83.4 percent, or $41,700, displacing consumption.

Turning now to project benefits, we assume for purposes of illustration that $90,000 of the $150,000 in annual benefits can be viewed as pure consumption that would be enjoyed by commuters (because of reduced traveling time) and by pedestrians (because of fewer accidents), while the remaining $60,000 would be cost savings to the health system (due to the reduction in accidents) that would be used to reduce taxes. Again, of the latter amount, 16.6 percent, or $9,960, would increase private sector investment and 83.4 percent, or $50,040, would increase consumption. Finally, in year 5, the liquidation costs would run to $30,000; of that, 16.6 percent, or $4,980, would displace investment and 83.4 percent, or $25,020, would displace consumption. The annual net changes in investment and in consumption are summarized in columns 2 and 3 of Table 3.[40]

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39 We assume that the proportion of the tax increase that displaces private investment equals the ratio of private investment to GDP for 1997. (See the discussion of method 4.)

40 The net changes in investment in year t, ΔI_t, equal:

$$\Delta I_0 = 0.166(-\$405{,}000) = -\$67{,}230,$$

$$\Delta I_t = 0.166(-\$50{,}000 + \$60{,}000) = -\$8{,}300 + \$9{,}960 = \$1{,}660 \quad (t = 1, 2, 3, 4),$$

$$\Delta I_5 = 0.166(-\$50{,}000 + \$60{,}000 - 30{,}000) = -\$8{,}300 + \$9{,}960 - \$4{,}980$$
$$= -\$3{,}320.$$

The net changes in consumption in year t, C_t, equal:

$$\Delta C_0 = 0.834(-\$405{,}000) = -\$337{,}770,$$

$$\Delta C_t = 90{,}000 + 0.834(-\$50{,}000 + \$60{,}000) = \$90{,}000 - \$41{,}700 + \$50{,}040$$
$$= \$98{,}340 \quad (t = 1, 2, 3, 4),$$

$$\Delta C_5 = 90{,}000 + 0.834(-\$50{,}000 + \$60{,}000 - 30{,}000)$$
$$= \$90{,}000 - \$41{,}700 + \$50{,}040 - \$25{,}020 = \$73{,}320.$$

In the second step, we multiply the changes in investment by the SPC to compute their consumption equivalents. The results, using our estimate of θ equals 1.92, are given in column 3. The third step sums the changes in consumption and in consumption equivalents to obtain the total changes in consumption, which are given in column 4. Finally, these amounts are discounted at the SDR to obtain the NPV. With s equals p_Z equals 0.02, the NPV is –$19,630, as shown in Table 3. As this NPV is negative, discounting using the SPC method suggests that the project should not proceed if the initial cost outlay is funded through taxes paid at the time the project is initiated.

Calculating the annual changes in investment and consumption is slightly more complicated when the project is financed through issuing bonds. The resulting amounts are presented in columns 1 and 2 in the second half of Table 3, but the detailed derivation is in Appendix B. Under these assumptions, the NPV is –$38,006.

The resultant NPVs illustrate that, when using the SPC approach, the NPV is usually smaller (less positive or more negative) if the project is financed by issuing bonds that are later repaid out of taxes than if the project is financed directly out of taxes. The main reason is that, when the project is financed by borrowing, the entire amount borrowed is lost to investment until it is repaid, and displaced investment is more costly than displaced consumption. The longer the repayment period, the smaller the NPV of a project financed through bonds relative to one financed directly out of taxes.

Criticisms of the Calculation and Use of the SPC. The SPC method accounts for increases and displacement of private investment and consumption in a theoretically appropriate fashion, which is an important advantage over other methods. Nonetheless, one can raise several objections. First, it is difficult to explain to policymakers how the NPV calculations are made, let alone why. Second, the information requirements are more formidable than for the other discounting approaches.

Third, judgment plays an important role, especially in deciding how to allocate benefits and costs between investment and consumption; hence the procedure can be manipulated to meet political objectives. Manipulation is not, however, unique to the shadow price approach. Whatever method of discounting is used, assumptions must be made and costs and benefits must be specified and estimated. These assumptions and estimates also involve judgment and can potentially be manipulated for political or other purposes.[41]

Finally, because the NPV depends on θ, which, in turn, depends on r_Z and p_Z or s_G, the results are subject to the same criticisms that pertain to the calculation of these parameters.

Perhaps because of the relative complexity of the method, we could not find any official use of the SPC method in practice.[42] Unofficial correspondence with the US Environmental Protection Agency (EPA) indicates, however, that it not uncommonly annualizes the capital costs of an environmental rule using the marginal rate of return on private investments, r_Z, and then discounts this flow using the marginal rate of time preference, p_Z or s_G. This approach is equivalent to using the SPC approach under very simple assumptions, as per our equation (7). Note, however, that, using our point estimates, the EPA's method gives values for θ of 5 (using p_Z) or 3 (using s_G), while we recommend a value closer to 2.

41 For a fascinating illustration of cost and benefit estimates that were politically influenced, see Hanke and Walker (1994).

42 Another reason the SPC method may not be used in practice is that government analysts may believe that, in an open economy, government borrowing does not displace private investment. Hence they may think there is no reason to adjust the costs and benefits by the SPC and, presumably, would prefer to use the government's long-term borrowing rate as the SDR (method 3). We believe, however, that even in an open economy government borrowing has to be repaid sometime, which will result in displaced private investment and consumption eventually, even if not immediately. Furthermore, as we discuss in the subsection on method 3, empirical evidence suggests that government borrowing in Canada does raise domestic interest rates and leads to immediate crowding out of private investment and consumption.

Method 8: The Time-Declining Discount Rates Approach

So far we have considered only constant (time-invariant) SDRs — that is, using the same rate to discount costs and benefits between years 51 and 50 as between years 1 and 0. There are, however, at least two reasons to consider a time-declining SDR — that is, using lower rates to discount costs and benefits that occur further in the future than those that occur sooner (see Harvey 1994).

The first reason is based on empirical evidence that individuals' marginal rates of time preference decline over time. Cropper, Aydede, and Portney (1992) provide survey evidence indicating that individuals use lower rates to discount events that occur farther into the future. Laibson (1997) cites evidence from the psychology literature that individuals' discount functions are approximately hyperbolic — that is, they are characterized by relatively high discount rates over short time horizons and relatively low rates over long horizons. He explains that individuals recognize that, if they cannot precommit to saving on a daily basis (using a high short-term discount rate), they will never save as much for the future as they know they should (using a low long-term discount rate). Recognizing their lack of self-control, individuals may commit themselves to savings plans with large penalties for early withdrawals while using their available credit to maximize their current consumption. They may, for example, simultaneously save by purchasing an illiquid asset with a relatively low after-tax real return (such as a Canada savings bond), make predetermined monthly mortgage payments, and borrow on a credit card at a very high real interest rate. These observed patterns of saving and borrowing simply reflect individuals' recognition of their lack of self-control and the time-declining discount rates that result. Borrowing on a credit card reveals a high rate of discount for the near future, while the first two choices could result from applying a low discount rate to the more distant future and so having a strong commitment to save for retirement. These time-shifting preferences explain the apparent profusion of candidates for p_Z discussed above in criticisms of method 2.

The second reason for using a time-declining SDR pertains to evaluating decisions with impacts that occur far in the future, such as environmental effects, including climate change. Constant market interest rates are particularly problematic when these rates exceed the growth rate of the economy, as has recently been the case.[43] The use of such rates implies that it never pays a society to spend even a tiny amount today in order to avert an environmental disaster that will destroy the economy's entire annual output, as long as that disaster will occur sufficiently far into the future. For example, if the Canadian economy produces $800 billion of output this year and is growing at a rate of 2 percent a year and if we use a 10 percent discount rate, then the present value of the economy's entire annual output three hundred years from now is only $116 today.[44] Many economists are uncomfortable with the implication that it is worth spending only $116 today to avert a total disaster in three hundred years. In contrast, given a time-declining SDR, the NPV of the future economy may remain material, implying that it is indeed worth saving what will prevail three centuries from now.

Even for less apocalyptic disasters, a large enough positive SDR gives negligible weight to costs and benefits that will occur sufficiently far into the future.[45] Using a time-declining rate avoids having to choose between ignoring very long-term environmental or health consequences (with a time-invariant nonzero SDR) and not discounting at all.

Weitzman offers two additional arguments for using a time-declining SDR. The first (1994) is an environmental rationale. He shows that s equals $r_Z[1 - W(1 + 1/E)]$, where s is the SDR (that is, the extra net consumption available at time $t + 1$ from a marginal

43 For example, analysis of data from Statistics Canada's CANSIM database shows that, from 1992 through 1995, the real after-tax rate of return on long-term government bonds consistently exceeded the annual growth rate of per capita consumption in Canada.

44 $PV = \frac{800(1 + 0.02)^{300}}{(1 + 0.10)^{300}} = \$0.000000116$ billion = $116.

45 For example, $1 in 100 years has an NPV of less than $0.01 if we use an SDR of more than 4 percent.

decrease in consumption at time t, while keeping the costs of environmental damage at a constant fraction of GDP), W is environmental cleanup spending as a fraction of GDP, E is the percentage reduction in environmental damage resulting from a 1 percent increase in cleanup spending, and r_Z is the marginal return to private investment, as in method 1. Weitzman argues that W will increase over time for two reasons. First, as environmental damage grows over time, the spending needed to clean it up will grow as a fraction of output because of diminishing marginal returns; second, the demand for a clean environment can be expected to increase over time with increases in per capita income. As W increases over time, given E, the SDR will decline.

More recently, Weitzman (1998) takes another approach that also results in a time-declining SDR. He proposes to resolve the dilemma of uncertainty regarding the choice of an appropriate discount rate by developing an operational methodology to determine the time-dependent schedule of effective discount rates appropriate for discounting long-term environmental projects. Having asked 2,160 economists to provide a single real rate to use in discounting the costs and benefits of global climate change, he finds that the frequency distribution of the respondents' rates approximates a gamma distribution. He suggests that the effective discount factor that should be applied to period t costs and benefits equals the average of all possible discount factors, constructed using his survey respondents' rates and weighted by the proportion of respondents who chose each particular rate. The discount rate effective at time t, denoted R_t, is then the percentage decline over time in the effective discount factor. His main finding is that, even if every respondent believes in a constant discount rate, the wide spread of opinion as to what is should be makes the effective SDR decline significantly over time.

Weitzman shows that R_t equals $u/[1 + t(v^2/u)]$, where u is the mean of the gamma distribution of the rates given in the survey, v^2 is the variance of these rates, and t is time measured in years. Had every economist agreed to a single common rate, then v^2 would have equaled zero and the SDR would have been u, the common rate. With disagreement, v^2 is greater than zero and R_t declines

hyperbolically from u at time 0 to its asymptote of zero at a convergence velocity equal to v^2/u.

Having rounded his estimates of u to 4 percent and v^2 to 9 percent, Weitzman suggests a sliding scale of SDRs: 4 percent for the near term (1–5 years), 3 percent for the medium term (6–25 years), 2 percent for the long term (26–75 years), 1 percent for the very long term (76–200 years), and 0 percent for the distant future (more than 200 years). He also argues that, if one were forced to choose a single, constant-equivalent discount rate to represent the entire sliding scale, it would be less than 2 percent per year.

Practical Implications for Selecting a Discount Rate

This essay raises several important points for discounting practice in Canada. The first is that, clearly, many alternative discounting methods exist. The choice among them can determine whether a proposed project has a positive or negative net present value and, therefore, whether or not it should be undertaken. The second important point is that the selection of social discount rate method and the procedure used in discounting depend on the specific circumstances surrounding the project. Third, many theoretical and practical issues surrounding discounting are unresolved. These issues may never be entirely settled, and even if they ultimately are, investment in public infrastructure projects cannot sensibly wait until this happens.

Table 4 summarizes our best judgment of the most appropriate discount method and rate to use in particular situations. Each of the six cells represents a different set of circumstances that affect the choice of the discount method and rate. The columns vary according to the length of the project, whether intergenerational issues are a concern, and whether there would be large future environmental or health effects. The rows vary according to whether the analyst can determine the portion of each benefit and cost that affects consumption and the portion that affects investment.

Each cell contains our best estimate of the appropriate SDR under the particular circumstances and, where appropriate, a

lower and upper bound in brackets. These bounds, which reflect the considerable uncertainty that surrounds the value of the SDR in particular circumstances, can be used in sensitivity analysis.

One implication of the table is that the current federal government practice of recommending a real social discount rate of 10 percent, with sensitivity analysis of up to 15 percent, is inappropriate. None of the rates in Table 4 is as high as 10 percent. Indeed, at best, that value is an extreme upper bound, appropriate only when a project would be financed through loans in a closed, fully employed economy, all benefits would be of relatively short duration, and all benefits would be received in the form of increased future consumption (see the discussion of method 1). These assumptions do not really apply in Canada.

If financial capital were perfectly mobile between Canada and the rest of the world and if the government could finance a project at the foreign borrowing rate and tax only the beneficiaries to repay the loan, then the SDR should be the real long-term borrowing rate — about 5 percent for 1997 and an average of 2 percent over the past 60 years (see the discussion of method 3). Again, however, these assumptions are unlikely to hold in practice. They would be violated, for example, if the current generation paid most of the taxes, but future generations enjoyed many of the project's benefits. Furthermore, there is evidence that capital is not perfectly mobile between Canada and other countries.

Table 4 is likely to apply in most practical situations. To use this table, analysts should first decide on the most appropriate row and then on the most appropriate column. Specifically, we suggest analysts should do the following:

- Determine whether it is feasible to divide the project's costs and benefits between the portion that would affect consumption and the portion that would affect investment. This can be done readily when pure consumption effects (such as increases or decreases in travel time) or pure investment effects would occur. In less obvious cases, we recommend, as a rough rule of thumb, using 16 percent — the ratio of gross business fixed capital formation to GDP in both recent years and historically — as

Table 4: ***Best Values of the Social Discount Rate under Different Circumstances***

Can Each Benefit and Cost Be Apportioned into the Amount that Would Affect Consumption and the Amount that Would Affect Investment?	Duration and Nature of Project Impacts		
	Short-Duration Project *or* Intergenerational Effects Not a Concern	**Long-Duration Project *and* Intergenerational Effects a Concern**	**Large Environmental or Health Effects in Future**
No			
Discount unweighted benefits and costs at:	with deficit financing: WSOC = 6.6% [5.0%, 7.7%] with tax financing: WSOC = 3.3% [0.7%, 5.3%]	s_G = 3.2% [2.1%, 4.6%]	R_t = 4% (years 1–5) 3% (years 6–25) 2% (years 26–75) 1% (years 76–200) 0% (years 200)
Yes			
Weight investment flows by the shadow price of capital:	θ = 1.92 [2.50, 1.56], then discount consumption flows and consumption equivalents at p_Z = 2.0% [0.0%, 4.0%]	θ = 1.69 [1.90, 1.48], then discount consumption flows and consumption equivalents at s_G = 3.2% [2.1%, 4.6%]	θ, then discount consumption flows and consumption equivalents at R_t, where θ = 1.56, R_t = 4% (years 1–5) θ = 1.72, R_t = 3% (years 6–25) θ = 1.92, R_t = 2% (years 26–75) θ = 2.17, R_t = 1% (years 76–200) θ = 2.50, R_t = 0% (years 200)

the share of benefits and costs assigned to investment. The remaining 84 percent should be assigned to consumption.

- If the analyst is fairly confident that benefits and costs can be appropriately apportioned between consumption and investment, use the discount rates in the bottom row. If the analyst is not confident, use the rates in the first row.
- If the discount rates in the bottom row are used, multiply by the SPC, prior to discounting, the benefits and costs that change investment. This calculation will take account of the fact that society underinvests because of taxes and other distortions and that it consequently should put a premium on resources that flow into and out of private investment. The value of this premium, the SPC, is 1.92 when used in tandem with a discount rate, p_Z, of 2 percent. For sensitivity analysis, use a lower bound of 1.5 (corresponding to a p_Z of 4 percent) and an upper bound of 2.5 (a p_Z of 0 percent).
- Determine whether the project is likely to generate benefits or costs that would affect generations not currently alive. If the project is of relatively short duration (say, less than 25 years), use the market-based rates given in the first column.
- If the analyst is using the upper-left cell (top row, first column), determine whether the project is likely to be debt financed; if so, use an SDR of 6.6 percent with sensitivity analysis between 5.0 and 7.7 percent. If it is likely to be tax financed, use an SDR of 3.3 percent with sensitivity analysis between 0.7 and 5.3 percent.
- If the project would be of relatively long duration, determine whether intergenerational effects are a concern. If they are not, then use the discount methods and rates in the first column.
- Remain aware of the two reasons the effects on future generations may be of concern. The first (discussed under method 5) is the belief that all future generations should be treated equally but, because of economic growth, the consumption of future generations should be discounted more than the consumption of the current one. Thus, if the project is of relatively long duration (say, more than 25 years) *and* the effects on future genera-

tions are of concern, use the discount methods and rates in the second (middle) column. The second reason (discussed under method 8) is that a project might have large environmental or health effects far in the future — for example, reducing the possibility of a large greenhouse effect. The use of a discount rate that exceeds the long-run growth rate of the economy implies that it would not be worth spending resources today to avert a total disaster that would occur sufficiently far in the future. Thus, if the project would either potentially avert or cause environmental or health effects in the distant future (say, more than 75 years from now), then use the methods and rates in the third column.

All of the discount rates in Table 4 fall below 7.7 percent, and most of them are within a fairly narrow range of 0 to 5 percent. Thus, reasonable NPV estimates of many projects may not be as sensitive to the specific discount rate used (the column that is selected) as to the decision on whether to use the SPC method (the row that is selected). Determining whether it is feasible to allocate benefits and costs between those accruing to investment and those accruing to consumption may be critical in discounting the costs and benefits from many projects.

Discounting of infrastructure projects has sometimes proceeded rather arbitrarily, perhaps with analysts being unaware of the assumptions implicit in their choices. This essay has shown how to categorize the key assumptions in a way that leads to a more rational choice of a social discount method and rate. Assumptions must still be made, but the outcome is less arbitrary and the choice, therefore, more defensible.

Appendix A: Derivation of the Shadow Price of Capital Formula

Several analysts, including Lind (1982) and Lyon (1990), derive formulas for the SPC that allow for depreciation and reinvestment. For example, Lyon shows that

$$\theta = \frac{\rho - f\rho}{s + \delta - f\rho}, \tag{A1}$$

where ρ is the gross return on capital prior to depreciation, δ is the depreciation rate of capital, f is the savings rate on the gross returns from this investment (that is, the fraction of the gross returns that are reinvested) and, as before, s is the social discount rate.

The proof of equation (A1) is fairly straightforward. Understanding it clarifies the meaning of f. Suppose an investment of \$1 yields a gross (before depreciation) return of ρ in the first period. The savings rate is f, so $f\rho$ is reinvested and $(1 - f)\rho$ is consumed. With depreciation of δ in this period, the total amount invested in the second period equals $1 + f\rho - \delta$. Similarly, in the second period, the return is $\rho(1 + f\rho - \delta)$, of which $f\rho(1 + f\rho - \delta)$ is reinvested and $(1 - f)\rho(1 + f\rho - \delta)$ is consumed. With depreciation of $\delta(1 + f\rho - \delta)$ in the second period, the total amount invested in the third period is $[1 + f\rho - \delta] + [f\rho(1 + f\rho - \delta)] - [\delta(1 + f\rho - \delta)]$, which equals $(1 + f\rho - \delta)^2$. And so on. Consumption in period 1 is $(1 - f)\rho$, consumption in period 2 is $(1 - f)\rho(1 + f\rho - \delta)$, consumption in period 3 is $(1 - f)\rho(1 + f\rho - \delta)^2$, and so forth. This consumption stream is a perpetuity with annual benefits of $(1 - f)\rho$ that grows at a constant rate, $f\rho - \delta$. Discounting this stream at s gives equation (A1).

In this formulation, r_Z is the net return on capital after depreciation — that is,

$$\rho = r_Z + \delta. \tag{A2}$$

Substituting from equation (A2) into equation (A1) yields

$$\theta = \frac{(r_Z + \delta)(1 - f)}{s - r_Z f + \delta(1 - f)}, \tag{A3}$$

which appears as equation (8) in the main text.

Appendix B: A Project Financed by Bonds — Illustrative Calculations of the Changes in Investment and Consumption Flows

When a project is financed by a $405,000 loan, we assume, following Harberger (1969), that the entire amount borrowed displaces private sector investment.[45] Given that the loan is repaid over five years at 5 percent interest, the equal annual instalments are $93,545.

For year 1, $20,250 (0.05 × $405,000) is interest on the loan and $93,545 – $20,250, or $73,295, is repayment of the principal. Consequently, at the end of year 1, immediately after the first annual payment, the loan balance equals $405,000 – $73,295, or $331,705. Extending this logic to subsequent years, it follows that $93,545 – (0.05 × $331,705), or $76,960, is paid toward the principal of the loan at the end of year 2, and $80,807, $84,848, and $89,090 are paid toward the principal at the end of years 3, 4, and 5, respectively. By the end of year 5, the loan is completely paid off ($73,295 + $76,960 + $80,807 + $84,848 + $89,090 = $405,000).

Again following Harberger, we assume that the full amount of each of the principal repayments goes toward increasing investment. Interest on the loan in year 1 is $20,250, as discussed immediately above. For years 2, 3, 4, and 5, the interest equals $16,585, $12,737, $8,697, and $4,455, respectively. Under the logic of the shadow price method, these payments should be treated symmetrically to taxes — that is, 16.6 percent as an addition to investment and 83.4 percent as an addition to consumption.

45 If the loans for the overpass were obtained from persons residing outside the municipality considering the project, the community may believe that benefits and costs accruing to these "outsiders" are irrelevant to its investment decisions and, therefore, ignore them in computing the project's net present value. Our computations of the project's NPV do not, however, allow for this possibility. Also, recall that the Harberger approach implicitly assumes a closed economy. If there is the possibility of borrowing from abroad, there will be less-than-complete crowding out of private investment. Private investment may also be less than completely crowded out if the economy has unemployed resources. See the discussion under method 1.

Now consider the $93,545 that is raised in taxes each year to pay for the loan. As before, we assume 16.6 percent, or $15,529, of these annual payments displaces private sector investment, while the remaining 83.4 percent, or $78,016, displaces consumption.

Finally, the remaining annual benefits and costs — the $150,000 in annual project benefits, the $50,000 in annual maintenance costs required to support the pedestrian overpass, and the $30,000 of liquidation costs at the end of year 5 — are treated exactly the same as before: net changes to investment equal $1,660 in years 1 through 4 and –$3,320 in year 5, and net increases to consumption are $98,340 in years 1 through 4 and $73,320 in year 5.

In summary, under these assumptions, the net changes in investment each year, ΔI_t, are:

ΔI_0 = –$405,000,
ΔI_1 = $73,295 + 3,362 – 15,529 + 1,660 = $62,788,
ΔI_2 = $76,960 + 2,753 – 15,529 + 1,660 = $65,844,
ΔI_3 = $80,807 + 2,114 – 15,529 + 1,660 = $69,052,
ΔI_4 = $84,848 + 1,444 – 15,529 + 1,660 = $72,423,
ΔI_5 = $89,090 + 739 – 15,529 - 3,320 = $70,980.

The net changes in consumption, ΔC_t, are:

ΔC_0 = $0,
ΔC_1 = $16,888 – 78,016 + 98,340 = $37,212,
ΔC_2 = $13,832 – 78,016 + 98,340 = $34,156,
ΔC_3 = $10,623 – 78,016 + 98,340 = $30,947,
ΔC_4 = $7,253 – 78,016 + 98,340 = $27,577,
ΔC_5 = $3,716 – 78,016 + 73,320 = –$980.

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Criteria for Infrastructure Investment: *Normative, Positive, and Prudential Perspectives*

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Infrastructure means the physical and human capital that broadly facilitates production, consumption, and further investment. Physical capital is now typically defined to encompass information technology infrastructure (Nelson 1993), as well as more traditional physical capital, such as roads, railroads, ports, and air transport facilities. Moreover, people increasingly recognize that governmental institutions, research and development, and education are forms of intangible infrastructure investment.[1]

Accumulated physical and human capital largely determine an economy's capacity for production and, increasingly, consumption. The historical evidence suggests that the state, both archaic and modern, has played a central role in developing this capacity (Johnson and Earle 1987; Gramlich 1994). Certainly in Canada, as in most industrialized countries, governments, along with the private sector, have been important in the development of core infrastructure, such as railroads, port facilities, and canals (Innis 1970).

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1 See Jorgenson and Fraumeni (1989); Adams (1990); Knack and Keefer (1995); Laroche, Merette and Ruggeri (1999); and Porter (1999a).

The empirical evidence, discussed at length elsewhere in this volume, indicates that public infrastructure investment is a determinant of economic growth and firm productivity, although analysts do not agree on the size of the effect. The World Bank, for example, concludes:

> While there is still no consensus on the magnitude or on the exact nature of the impact of infrastructure on growth, many studies on the topic have concluded that the role of infrastructure is substantial, significant, and frequently greater than that of investment in other forms of capital. (1994, 15.)

Other reviews of the evidence are more cautious (Mintz and Preston 1993). As the magnitude and specific source of the impact of public infrastructure is still unclear, therefore, so is the appropriate role of the public sector in influencing its size and composition.

In Canada, as in all modern market economies, private decisions determine the composition of most capital investment in infrastructure. Yet a variety of factors, including a lack of incentives for market participants to supply many public goods, network externalities (market failures), and transaction costs — such as those resulting from strategic behavior by holdouts in land assembly for location-specific investments — make it virtually certain that the private sector will not provide all socially valuable investments. These barriers to optimal private investment most often arise with respect to infrastructure. Government, therefore, has a legitimate role in shaping infrastructure development by undertaking, facilitating, and encouraging (or discouraging) specific investments.

Some research suggests that the optimal fraction of public physical capital in an economy may be as high as about 40 percent of total physical capital (Aschauer 1998, 11). Other analysts (such as Hulten and Schwab 1993) are, however, much more sanguine. David Gillen (elsewhere in this volume) reviews the evidence on the aggregate impact of government infrastructure investment, especially its macroeconomic impacts. The microeconomic impacts are likely to be just as important — indeed, perhaps more so. Michael Porter, for example, argues that the competitiveness and productivity of firms in a national economy are strongly influenced

by the quality of the microeconomic business environment, including the physical, administrative, information and technological infrastructures. He provides evidence that information technology infrastructure and technology infrastructure generally are increasing in relative importance (1999b, 34–35).

Just as most people have to put their pants on one leg at a time, governments have to engage in infrastructure investments one project at a time. Specific projects may be either socially wealth reducing or wealth enhancing. Additionally, while many infrastructure projects may be individually valuable, the high levels of taxation needed to finance them may reduce economic growth rates (Scully 1991; Besci 1996; Diewert, Lawrence, and Thompson 1998). Recent empirical evidence from the United States suggests that domestic (nondefense) investments, including physical infrastructure, may be the only kind of incremental government spending for which the spending-tax tradeoff is positive (Niskanen 1998, 149).

Government's role in infrastructure development raises three questions.

1. What criteria should government use in making infrastructure decisions?
2. How well can one expect actual government infrastructure investments to meet these criteria?
3. If a gap exists between what is desirable and what actually occurs, what is the best way of resolving it?

The most common approach to answering the first question is to adopt a *normative framework* that assumes government will apply criteria consistent with some set of social goals. A method explicitly developed to guide the selection of efficient public investment projects is cost-benefit analysis (CBA), which takes account of the costs and benefits that accrue to all members of society (Boardman et al. 1996).[2]

2 It thus differs from the calculus of individuals, who typically make decisions based only on their own costs and benefits.

Alternatively, a broader normative framework *begins* with cost-benefit analysis but adapts it to take account of its conceptual and practical limitations. One conceptual limitation is an exclusive focus on efficiency at the expense of distributional values. *Multigoal analysis* both incorporates additional social goals beyond efficiency and compensates for those aspects of cost-benefit analysis that generally cannot be reliably implemented (Weimer and Vining 1999).

An approach to answering the second question is to recognize the existence of pervasive government failures, the systematic ways that the decisions of governments fail to achieve the efficient use of resources (Cordes 1997; Weimer and Vining 1999). In choosing public policies, all democratic governments face powerful incentives to emphasize goals that favor the direct interests of politicians and bureaucrats (or the interest groups that influence them). Canadian governments are certainly not immune to this form of government failure, as illustrated by a range of industrial policy fiascos, including Human Resources Development Canada's (HRDC's) jobs program and British Columbia's "fast" ferries (three car-carrying catamarans that were to ply between Vancouver Island and the Lower Mainland). Offsetting the likelihood of government failure requires a *positive* analysis of government infrastructure decisions to identify the specific incentives that governmental actors face and to model their likely decisions and actions.

Addressing these two questions provides a framework to address the third question: What is the best way of closing the gap between normative criteria and positive behavior? In more practical terms, one can restate the question as: How can decisionmakers shape policy institutions so that they provide socially valuable infrastructure despite the incentives for inappropriate investments inherent in representative governments? What is needed is a *prudential framework* for government infrastructure decisions. Such a framework requires adapting the normative criteria both to take account of the positive analysis and to develop institutional arrangements that dampen the incentives of governmental actors to pursue their own self-interest. Politicians and bureaucrats will always have a tendency to pursue their individual self-interest — water runs downhill. But a great deal of evidence suggests that the institutional incentives and constraints they face shape their spe-

cific behavior (Shepsle and Weingast 1981). In short, institutions and institutional design, including quite micro-institutional features, matter (Weimer 1995; Goodin 1996).

Our first task in this essay is to describe relevant normative criteria and to consider the conceptual and practical limitations of social cost-benefit analysis. Second, we provide a positive assessment of government decisionmaking concerning infrastructure, drawing on empirical studies of choice as well as the use of cost-benefit analysis within government. Third, we reassess the normative criteria in terms of the positive assessment. Finally, we provide more realistic prudential criteria for government infrastructure choices and propose some relatively modest and practical institutional changes.

A Normative Perspective on Infrastructure Choice

What criteria should government use in making infrastructure-shaping decisions? Cost-benefit analysis provides a starting point for developing criteria for evaluating proposed projects. The initial impetus for this approach arose in the evaluation of proposed dams, irrigation, harbor, and other water-related infrastructure projects in the United States, especially as required by the *Flood Control Act of 1936* (Steiner 1974). Over the past 50 years, economists have continuously refined the conceptual basis of CBA, demonstrated its use beyond infrastructure projects, and improved its application.

Anyone who accepts the premise that public projects should be based on the goal of maximizing economic efficiency would probably also argue that the criteria for evaluating infrastructure should not only start with CBA but end with it as well. Our view is that CBA would often be the appropriate approach *if it could be fully implemented*. But we join several other observers (Millar 1989; De Brucker et al. 1995; Mhango 1995; Adler and Posner 1999) in proposing criteria that can be more realistically implemented by government officials with routinely available information.

Fundamental CBA Principles

Welfare economics makes normative assessments in terms of Pareto efficiency: an allocation of factors and goods such that no person could be made better off without making someone else worse off. The status quo is Pareto-inefficient if an alternative to it can be found that would make at least one person better off without making anyone else worse off. The goal of efficiency is advanced by selecting the Pareto-superior alternative over the status quo.

Applied welfare economics uses *potential* Pareto efficiency, a less stringent standard for comparing the relative efficiency of alternative projects. An allocation is potentially Pareto-efficient if it creates sufficient gains for those made better off such that they could conceivably fully compensate those made worse off. An allocation is potentially Pareto-superior to the status quo if it would yield an excess of benefits over costs. (If the aggregate net benefits accruing to all persons are positive, then it is conceptually possible to allocate the excess of benefits over costs so that no one is made worse off than under the status quo and some are made better off.) In applied welfare economics, the most efficient allocation among a set of mutually exclusive allocations is the one that maximizes net benefits.

Applying the net benefit criterion requires measurement of benefits and costs. The benefits of projects are measured in terms of people's willingness to pay (WTP) to obtain them. In theory, WTP corresponds to the maximum payments that could be taken from people (or given to them in the case of projects that produce undesirable impacts) so that they are indifferent between the status quo and the alternative project with the payments. The benefit of a project is the sum of these payments, which could be positive or negative. Aggregate WTP is usually estimated from information about the markets in which the goods produced by projects are traded. Where markets do not exist, economists have developed techniques relying on observed behavior, such as travel costs or other expenditures made in connection with consumption of nonmarket goods, and on contingent valuation surveys that attempt to elicit WTP through questions posed about hypothetical changes in nonmarket goods (Boardman et al. 1996).

Most projects involve costs. Those that require resources to produce their impacts involve opportunity costs in terms of the goods that could have been produced by these resources if they were not used for the project. For many resources, opportunity costs can be estimated from information about the markets in which they are traded.

Two factors complicate the measurement of net benefits. First and almost always relevant to infrastructure projects, costs and benefits accrue over extended periods of time. Because people generally prefer consumption sooner rather than later and consumption today comes at the expense of investment that would provide more consumption in the future, benefits and costs accruing in the future must be discounted. As Moore, Boardman, and Greenberg discuss elsewhere in this volume, alternatives should be compared in terms of the present value of their net benefits. The long life of most physical infrastructure projects makes the selection of the discount rate important; small variations in the discount rate can result in large changes in the present value of net benefits.

Second, the costs and benefits of many projects depend on uncertain contingencies. In any particular season, for example, the actually realized benefits from a dam will depend on weather conditions. Conceptually, the cost-benefit analyst would like to know how much a person would be willing to pay for the dam *before* knowing what weather will actually be experienced. This amount, called the *option price*, is the appropriate benefit measure. In practice, however, analysts typically approximate the option price by the expected surplus, which is calculated by assigning probabilities to representative contingencies and then computing a weighted average of the surpluses that would be realized under each contingency. Taking uncertainty into account in this way leads to choosing projects that maximize the present value of expected net benefits.

Deviations Based on Conceptual Issues

The conceptual basis of cost-benefit analysis is not immune to challenge. Critics object to its exclusive focus on efficiency. They also raise questions about whose costs and benefits should count. These

conceptual issues have particular relevance to the assessment of large infrastructure projects.

Distributional Values

Although one can conceptually incorporate distributional values into benefit measures by eliciting people's willingness to pay for alternative states of the world that have specific distributions of goods (Zerbe 1998), doing so would render cost-benefit analysis largely impractical. Analysts may impose weights on the costs and benefits accruing to different groups in order to give relatively larger net benefits to projects that help specific groups, such as those with low income. However, three problems emerge: costs and benefits are difficult to disaggregate among relevant groups, analysts usually have no clear basis for selecting particular weights, and the use of weights submerges value judgments within the net benefit measure, which would be better examined explicitly.

Consequently, we argue that CBA should be viewed as a means for comparing alternative infrastructure projects in terms of efficiency *excluding* other goals, such as equity and fairness. One rationale for this limitation is that, if CBA is consistently used and those who gain and lose differ across projects, it will tend to make everyone better off over the full range of its application.

Legitimate distributional concerns sometimes conflict with efficiency in the selection of infrastructure projects. WTP estimates are generally higher for a project to produce benefits in a high-wealth area than for a similar project to produce benefits in a low-wealth area. But few would consider it socially desirable if, for example, road improvements and tree planting were done only in wealthy neighborhoods. Similarly, many types of infrastructure produce greater net benefits in densely populated urban areas than in sparsely populated rural areas.

In addition, infrastructure projects often involve substantial costs to specific areas or groups during construction or afterward. For example, the lowest-cost construction method may concentrate costs on a small group of users; an example is closing an access road completely rather than leaving it open for limited traffic. Cit-

izens who are motivated by concerns of fairness and politicians who must respond to complaints will generally trade somewhat higher construction costs for smaller negative impacts on specific groups.

Inside and Outside Jurisdictions

An infrastructure project often involves costs and benefits for those living outside the region where it occurs. For example, a road traversing a province may well provide a large share of its benefits to nonresident motorists. And because much infrastructure investment results from decisions made by provincial and local governmental units, the issue of standing often arises with respect to the treatment of costs and benefits external to the jurisdictions.

Taking the country as the political and economic unit, most economists argue that cost-benefit analysis should view all legal residents as having standing in the estimation of costs and benefits no matter where they live. Of course, infrastructure projects may also have impacts that spill across international borders and elicit responses from other countries, suggesting that a supranational perspective may sometimes be important. More relevant to infrastructure decisions, however, are decisions by subnational governments. They have an incentive (and, some may reasonably argue, a duty) to be responsive to their own constituencies; further, governments closer to problems may have better information relevant to the choice of appropriate solutions.

A common type of standing problem arises when grants from national to subnational governments are earmarked for specific infrastructure projects. From the social perspective, these grants represent benefits to the residents of subnational jurisdictions. Because the residents of most regions pay only a fraction of the national-level taxes used to fund the grants, subnational governments have an incentive to focus on the benefits and ignore the costs that are borne by residents of other regions.

How should subnational governments view such external effects? In other words, what should be the extent of standing in subnational governments' application of CBA? As argued above, the usual normative CBA answer is that it should be based on

national-level standing. An alternative answer, consistent with the democratic principle of locating policymaking as close as possible to those affected by it, is that subnational governments should adopt a subnational perspective in their CBAs provided that the national government adopts policies that encourage subnational governments to take account of important externalities in their decisionmaking.

In Canada, where significant public policy is made at both the federal and provincial levels, a plausible normative case can be made for this answer: subnational governments are best able to assess costs and benefits accruing within their jurisdictions and national governments are best able to assess the magnitude of externalities that spill over to other jurisdictions.

A related issue arises in the context of projects involving substantial risk. The federal government is better able to borrow and spend in adverse economic circumstances; therefore, it is generally better able to bear project risk than are provincial or local governments. Consequently, adopting very risky projects with high expected net benefits is more reasonable from the national perspective. If the estimation of WTP is based on option price rather than on expected surplus, risk will be fully taken into account in the benefit measure. As noted above, however, option price is difficult to estimate in practice. Consequently, subnational governments' thinking about large-scale projects may reasonably take account of the probability of realizing negative net benefits as well as expected net benefits.

The issue also arises in the context of discounting. CBA requires the use of a social discount rate. Provincial and local governments are likely to view their borrowing rate, which represents their opportunity cost of capital, as the appropriate discount rate for their projects. This rate, however, is likely to be higher than the social discount rate (Boardman et al. 1996). Thus, using the borrowing rate may discourage some investments that would otherwise have positive net benefits. (This factor is one that runs counter to the general tendency for subnational governments to overestimate the net benefits of infrastructure projects.)

Deviations Based on Practical Issues

Efforts to apply cost-benefit analysis often fall short because analysts face practical difficulties in applying its principles. Several of these difficulties are especially severe for infrastructure projects.

First, projects often have costs and benefits that accrue over lengthy periods. Long horizons place an extra burden on analysts who must predict and value future consequences (Boardman, Mallery, and Vining 1994). As noted above, it also means that the present values of net benefits of alternative projects are likely to depend greatly on the selected social discount rate.

Second, infrastructure projects often have effects that cannot be easily incorporated into net benefits. For example, environmental effects are often hard to predict quantitatively and are usually even more difficult to monetize. These problems are particularly evident with natural resources, such as wilderness areas, whose benefits come from both use and nonuse (Vining and Weimer 1998). For example, some Canadians may derive benefits from hiking in wilderness areas (a use benefit) and from simply knowing that the wilderness is available for future hiking (a nonuse benefit). One nonuse benefit, *existence value*,[3] often comes into play in valuing environmental goods and the outputs of certain kinds of infrastructure projects. For example, some people have altruistic motivations that make them willing to pay to provide services such as running water to people who would otherwise not have them.

Another nonuse benefit, *option value*, is frequently relevant in assessing infrastructure, especially transportation infrastructure. People may be willing to pay something for an infrastructure project whose services they may wish to consume in the future. For example, some people who do not now rely on mass transit may be willing to pay something to have it available to use in the future. These existence values should be incorporated into project benefits, though doing so is difficult.

3 A good has existence value if individuals are willing to pay for its preservation even though they have no expectation of directly consuming it.

Finally, infrastructure projects sometimes involve the use of unique resources whose future value is uncertain. For example, analysts are inevitably unsure about how much the next generation would value a wilderness that will be lost if a major highway is built. Delaying irreversible development may provide an opportunity to learn about future valuations and perhaps preserve the unique resource. This benefit has been labeled *quasi-option value* (Arrow and Fisher 1974; Fisher and Hanemann 1987). It has a somewhat weaker conceptual basis than existence and option value (if enough information were available to measure it, CBA would incorporate it).

Multigoal Analysis

The conceptual and practical limitations to applying cost-benefit analysis suggest that it alone is unlikely to be an appropriate general rule for evaluating alternative infrastructure projects. Where it can be practically applied, CBA does provide a guide for measuring progress toward efficiency, which is one important goal. Even where its application is seriously impeded by practical limitations, however, it can still help to guide the valuation of specific projects' impacts in the context of a multigoal analysis. The term *multigoal* indicates that it is appropriate to consider more than one value in comparing alternative policies. We seek here to summarize a practical framework for multigoal analysis of infrastructure projects.

Table 1 sets out our proposed framework for such an analysis, using six general categories of criteria.

- *Social benefits and social costs* provide the basis for assessing projects in terms of efficiency. When all costs and benefits can be monetized, these two general categories can be combined into a single measure of the present value of expected net benefits, the appropriate metric for measuring efficiency. Note, however, that confidence about monetization depends on the capabilities of the evaluating jurisdiction — its expertise, staff time, and data availability — as well as the nature of the impacts being evaluated. For example, some analysts are prepared to

estimate the number of commuter hours saved by a highway project but not to place a dollar value on these hours, while other analysts are quite comfortable with the CBA convention of valuing commuter time at approximately half the median wage rate of the commuters (Boardman et al. 1997). Other impacts, such as those that affect the quality of the environment, may not be easily quantified, a difficulty that should not exclude them from consideration. Consequently, qualitative descriptions are likely to join both monetized effects and quantitative assessments in the list of important effects.

- *The jurisdictional fiscal impacts* of the project are included here in recognition of the fact that jurisdictions face institutional (and political) constraints on raising revenue, so that they must sometimes forgo projects that would otherwise be socially efficient. Fiscal impacts are normative in the sense that expenditure levels reflect, however imperfectly, the preferences of the relevant jurisdiction's polity for government activity; taking account of these impacts keeps attention on the link between spending and taxes. The expenditure stream, which typically includes construction costs and subsequent operating costs and debt service, indicates the financial liability that the jurisdiction would assume by adopting the project being evaluated. Offsetting these financial liabilities may be revenues from the project. To the extent that these expenditures and revenues can be confidently quantified, the time profile of net revenue and its present value can be used to summarize the overall fiscal impact of the project. While various budgeting practices, such as moving project costs "off budget," may obscure those impacts, they are likely to be apparent to bond-rating organizations. Consequently, they are relevant to the assessment of jurisdictions' fiscal credibility by capital markets.

- *Distributional impacts* identify groups that would bear disproportionate costs or benefits from the project. It is generally informative to distinguish the groups that would encounter disproportionate costs during the construction phase of the project from those that would bear them during its useful life.

Table 1: *A Normative Framework for Evaluating Infrastructure Projects*

General Categories of Values (Criteria)	Components
Social benefits	Impacts that can be confidently monetized: *Value of marketable goods, such as electricity and irrigation water*
	Impacts that can be quantified but not confidently monetized: *Typically, effects on nonmarketed goods, such as health, safety, and time*
	Impacts that cannot be confidently quantified: *Typically, existence and option values*
Social costs	Impacts that can be confidently monetized: *Real resources purchased in markets*
	Impacts that can be quantified but not confidently monetized: *Typically, real resources not traded in markets, such as time*
	Impacts that cannot be confidently quantified: *Typically, real resources with unique characteristics, such as use of wilderness areas*
Jurisdictional fiscal impacts	Expense stream: *Construction and operating costs payed by governmental sponsor*
	Revenue stream: *Project revenue and intergovernmental transfers realized by governmental sponsor*
Distributional impacts	Concentrated costs to groups during construction: *Substantial inconvenience or service loss suffered by groups during construction*
	Concentrated costs to groups after construction: *Substantial inconvenience or service loss suffered by groups from completed project*
	Concentrated benefits to groups after construction: *Disproportionate share of gains received by groups from completed project*
Project risk	Benefit uncertainty: *Likelihood project would fail to produce expected benefits*
	Cost uncertainty: *Likelihood project would involve substantially higher-than-expected costs*
Extrajurisdictional impacts	Positive spillovers to other jurisdictions: *Project benefits not realized by jurisdictional residents*
	Negative spillovers to other jurisdictions: *Project costs not realized by jurisdictional residents*

Construction-phase costs, such as higher noise levels and business disruption, may be intense even if temporary and may result in significant costs or even bankruptcies for businesses. Even less severe costs over the life of a project (typically long in the case of infrastructure) can accumulate into substantial losses.

- *Project risk* is almost always involved in infrastructure investments (as discussed above). It can be reasonably broken down into the risk that benefits will be much less than their expected value and that costs will be much greater than their expected value. Yet estimates of the social benefits and fiscal impacts are likely to be made in terms of expected values that obscure considerable risk of loss to a jurisdiction. Imagine a project that has a 25 percent chance of producing a present value of net benefits of $100 million and a 75 percent chance of producing a present value of net benefits of –$20 million. Although the project offers an expected present value of net benefits of $10 million [90.25 × $100 million) + (0.75 × –$20 million)], it is three times more likely to produce a social loss than a social gain. From the perspective of a regional jurisdiction with a small portfolio of projects, the high risk of the project provides a legitimate concern about its desirability.

- *Extrajurisdictional impacts* can be important (as discussed above). Putting aside any moral responsibility regional governments may have to promote national as well as regional welfare, large negative spillovers are likely to undercut support for projects, while large positive spillovers are likely to increase them. Identifying these spillovers can also help to provide a better understanding of distributional impacts. For example, project revenues that are collected from nonresidents may reasonably be viewed as more beneficial for the jurisdiction than revenues that come from residents and thus come at the expense of other local spending.

In conclusion, multigoal analysis typically encompasses, rather than fully replaces, CBA. Efficiency is almost always an important goal in the evaluation of infrastructure projects. CBA provides the

basis for assessing efficiency; multigoal analysis allows other values to be incorporated along with efficiency or the full accounting of efficiency if CBA cannot be comprehensively implemented.

A Positive Perspective on Infrastructure Choice

How well do actual government infrastructure investments meet appropriate criteria? Attempting to answer this question realistically requires understanding government decisionmakers and the environment in which they work. Over the past 25 years, political scientists and economists have begun to develop more fully a positive theory of government (Mueller 1997). Here we review those aspects of the theory that are most relevant to considering governments' incentives to engage in efficient or inefficient infrastructure development. In doing so, we recognize that incentives are shaped by the political institutions within which governmental decisions are made.

Infrastructure development in Canada is dominated by two interrelated features of the institutional environment: parliamentary democracy, and the high degree of constitutional and practical authority exercised by the provinces. While neither is totally immutable, both are features and results of the Constitution and are, therefore, relatively stable and permanent features of the system (Brennan and Buchanan 1985; Frey 1988; Buchanan 1989). These institutional features profoundly shape both the demand for infrastructure, as articulated by elected representatives, and its supply, whether civil servants provide it directly, furnish it indirectly through contracting procedures, or shape it through regulation.

The Impact of Parliamentary Discipline

Parliamentary representative government, as opposed to presidential-congressional-style representative government, requires much more effective party discipline, which, in turn, typically means much greater political centralization of power (Moe 1990). As a

corollary, parliamentary systems have much less room for individual representatives, whether MPs or their provincial equivalents, to articulate *effective* demand for infrastructure projects.[4] Thus, most Canadian federal and provincial politicians have fewer opportunities for individual, constituency-based vote-maximizing behavior than have their US counterparts (Weingast, Shepsle, and Johnsen 1981; Baumgardner 1993).[5]

The creation of a parliamentary committee system by the Progressive Conservative government in the 1980s did increase somewhat the influence and visibility of individual MPs (Brander 1995), but not enough to affect fundamental political realities. Indeed, this system probably has been more than offset by the continued centralizing tendencies around the prime minister (Savoie 1999).

Legislators Appealing to the Riding Level

Maximizing constituency votes presents a problem when the interests of a particular riding conflict with the normative criteria described earlier. As Savoie (1990, 184) succinctly points out, "There is never...a lack of infrastructure projects to be financed." Pork-barrel spending can occur for a number of reasons. First, although the total costs of a project may exceed its total benefits, most of those benefits may accrue to the constituency while the costs are widely dispersed across the country. Second, because project expenditures — such as the wages paid to construction workers building the project — only reflect the opportunity cost of the labor, constituents typically regard such costs as *benefits* of the project if they are expended within the riding.[6]

If legislators can obtain the public credit for particular projects, many potential infrastructure investments are ideal candidates for

4 Even within parliamentary systems, however, institutional design features matter a great deal. The postwar Japanese parliamentary system has encouraged immense legislator pork-barreling (Ramseyer and Rosenbluth 1993).

5 The same is true within provincial legislatures compared to those of US states.

6 Wages well in excess of opportunity cost may offend some voters but will certainly garner support from the recipients.

attracting constituency votes because they are location specific and tangible, involve considerable accumulation of physical assets ("sunkness," which usually offers some credible commitment to future spending), and are labor intensive (at least from the constituency's accounting perspective). But the parliamentary system makes it difficult for individual legislators to vote-maximize *directly* in their constituencies because of their inability to influence the legislative agenda strongly, whether related to lawmaking or expenditures.

It is also difficult for them to use infrastructure projects to vote-maximize indirectly by influencing the behavior of the bureaucracy. Backbench MPs have little power to threaten civil servants with targeted budget cuts or unpleasant appearances before legislative committees with teeth. Quite naturally, civil servants tend to meet more readily the demands of politicians who control their careers and budgets. Finally, but importantly, this lack of both direct and indirect power means that individual MPs are less attractive targets for either the support or threats of interest groups.

Some majority-party politicians do have the power to engage in constituency vote-maximizing behavior, most notably the prime minister, senior cabinet members (especially those with regional responsibilities), and the ministers of agencies that are directly involved with various kinds of infrastructure spending (Savoie 1990). Prime ministers, for example, are well known for infrastructure spending in their own ridings. The recent political scandal about HRDC's job grants illustrates the high degree of centralized political control that is now typically exercised in discretionary spending (Fife and McIntosh 2000) and how closely it is linked to the electoral cycle (the Opposition has highlighted the big spike in HRDC job spending during the six months preceding the 1997 federal election).

Yet even these political actors are somewhat constrained by a number of factors. First, the power of such senior politicians depends almost totally on their party's maintaining a large (usually geographically dispersed) majority in Parliament, a fact that provides individual MPs and their provincial counterparts with their greatest leverage to lobby cabinet and ministers for projects in their

ridings (Munro 1975). Second, current practice is to shuffle ministers frequently.[7]

Third, it is difficult for cabinet ministers, a small group of temporary political actors, to monitor, control, and micromanage large federal bureaucracies effectively when civil servants have a conflicting agenda. Departmental ministers are inevitably heavily dependent on their permanent deputy ministers, especially in program areas that require extensive technical and implementation expertise.

Of course, the agendas of politicians and civil servants are sometimes broadly congruent, most commonly when the politicians demand new programs and higher levels of spending. Congruence appears to have largely been the case in the 1970s and 1980s, when both federal and provincial government spending as a percentage of the economy rose rapidly (Richards 1997; Atkinson and Bierling 1998).

Legislators Appealing to the Regional Level

Politicians at the national level may also engage in a form of vote-maximizing behavior that has some similarities to constituency vote maximization but is based on regions rather than ridings. It is likely to be especially pervasive when parties fractionalize along regional lines, a situation that emerged after the 1993 election when the great majority of the governing Liberal Party MPs had been elected from Ontario, with the Reform Party dominating in the West and the Bloc Québécois in Quebec. Attempting to buy regional votes at the expense of the national polity typically requires a more complex calculus than that faced by a politician focused on a single riding. Being a bigger subset of the nation than a riding, a region bears a higher percentage of both the budgetary cost and the excess tax burden of infrastructure projects, while the benefits have to be spread over a greater number of beneficiaries. Moreover, a big

7 Indeed, this practice may partly be an institutional response to the tendency of long-serving ministers to engage in pork-barreling at the expense of their colleagues.

region has less room than a small one to receive transfers from the rest of the country; thus, its expected net benefits from redistributional projects are typically lower. An encompassing rich region may well find that, given its relatively high tax share, demanding such projects is a losing game (Olson 1982, 47–52).

Given these problems, senior politicians are tempted to minimize expenditures by trying to trade on voters' intertemporal myopia by boosting regional infrastructure spending late in the electoral cycle (Nordhaus 1975; Paldam 1997). Such timed spending occurs at the federal level in Canada:

> [I]n 1980 the winning party promised new measures, including double-tracking rail lines, to develop the West; in 1979 the winning party promised a larger regional development department with a strong presence in three of the four major regions of the country; in the 1974 campaign the government pledged specific development measures for western Canada...and in the 1972 campaign a "blockbuster" commitment was made to Toronto, including plans for a new $30 million, eighty-acre waterfront park. (Savoie 1990, 184.)

The same pattern can be observed in provincial elections (Spafford 1981). Indeed, if provincial political actors view federal revenues as a "commons" where the money they obtain will essentially come from other regions, pursuing such projects is rational from a regional perspective (Savoie 1990).

The Role of Civil Servants

Civil servants are the ones who must, one way or another, deliver publically financed infrastructure (even if the design and construction is carried out by private sector contractors). And just as politicians have their own interests, so do civil servants (Tullock 1965; Downs 1967; Savoie 1990).

One approach to analysis here explicitly treats politicians as demanding services that are supplied by civil servants. Niskanen (1971) makes the extreme assumption that, in attempting to maximize their utility, civil servants can behave like perfectly price-

discriminating monopolists. Under these circumstances, it is plausible to assume that they attempt to maximize their total budgets. A less extreme assumption is that civil servants are more like monopolists who cannot price discriminate. With this assumption, it is more plausible that civil servants are concerned with maximizing not their total budget but rather the portion of it that they can use for purposes that give them personal utility — in other words, their discretionary budget, which is essentially equivalent to a monopolist's profit (Migué and Bélanger 1974; Niskanen 1975; Kraan 1996). Under this assumption, civil servants normally have incentives to reduce the total budget below its optimal size, in the same way that a monopolist has incentives to reduce output below the competitive output level.[8]

Of course, one can also plausibly argue that the assumption that civil servants have even this degree of monopoly power is too strong (Breton and Wintrobe 1975; Wintrobe 1997). In parliamentary systems, elected ministers have direct supervisory control of their ministries that allows them to acquire considerable information about costs. They can also draw on specialized agencies, such as the Treasury Board, that have specific responsibility and expertise in assessing the relationship between costs and output.

The budget-maximizing approach can also be criticized on the more fundamental grounds that bureaucratic utility is not consistently related to the size of the budget. Indeed, Dunleavy (1992) argues that individual bureaucrats are unlikely to devote resources to attempting to maximize the budget because its size is essentially an organizational public good — that is, all bureaucrats tend to benefit regardless of whether they devote any effort to increasing it (Vining and Weimer 1996). It is more rational for individual civil servants to directly pursue organizational private goods, such as promotion and perks, on which no one else can free ride.

If senior bureaucrats seek to maximize such private goods, including mobility and subsequent private sector jobs, then they usually need to build support outside their own department

8 Keeping in mind that optimality in this context assumes that politicians are accurately representing citizens' demands.

(Kraan 1996). Building such support may mean that reducing their own budgets is advantageous in certain circumstances for bureaucrats, especially senior civil servants (Dunleavy 1992) and those who are specifically in budget guardianship roles (Boardman, Vining, and Waters 1993). On the other hand, civil servants in project-delivering ministries typically do have powerful incentives to increase their project budgets because *both* project costs (for example, expenditures on highway construction) and project benefits (for example, time savings on a new highway) accrue to constituencies that are valuable to them (ibid.).

The personal incentives that offset budget-maximizing behavior are likely to be less important in smaller, less differentiated provincial bureaucracies.

The Role of Federalism

The second feature of the constitutional institutional environment that shapes governmental spending, especially infrastructure spending, is the decentralized nature of the Canadian federation (Gibbins 1982; Stevenson 1987; Stanbury 1993). The *British North America Act* of 1867 allocated to the provinces many powers relating to infrastructure spending. These powers, along with other features of a decentralized federal system, have persisted.[9]

Today, the concentration of francophones in Quebec, coupled with a credible threat of secession, provides a demand for decentralization as well as a basis for the existence of provincial parties. Further, provincial (or at least regional) economies are quite divergent, with differing bases of comparative advantage and with emerging, segmented north-south economies that create differences in policy preferences (Courchene 1994, 13–14).

Nationally organized parties have never subsumed provincially organized parties in Canada (Johnson 1980). In addition to the underlying pressures for decentralization, holding federal and

9 Historically, in the 80 years following the BNA Act, the Privy Council of the British House of Lords, then Canada's highest court of appeal, generally found for the provinces in disputes over the allocation of authority.

provincial elections at different times fosters provincial party independence and allows centrist voters to split their votes more easily so as to balance the position of a sitting government at one level with that of a newly elected government at the other level (Gallego 1998).

Given these realities, it is perhaps not surprising that provincial politicians have a tendency to prey on the incipient paranoia of their voters, claiming that their province is not getting its fair share of federally funded projects. "Provincial premiers can always count on the support of their electors whenever they take aim at federal policies to explain the underdevelopment of their regions" (Savoie 1990, 271).

The vote-maximizing game between federal and provincial politicians is, however, a complex one. Federal and provincial politicians do not *directly* compete for votes, nor do provincial politicians in different provinces. Frequently, provincial politicians do attempt to garner votes at the expense of their opponents by suggesting to their constituents that, relative to residents of other provinces, they are getting more than their fair share of projects that fall within federal or concurrent jurisdiction (ibid., 341). Sometimes, however, such politicians attempt to maximize votes by complaining that the province is currently getting less than its fair share of resources but arguing that their party has the best strategies to redress the imbalance. (This game was dampened during the recent large cutbacks in federal transfers but will intensify again as Ottawa gets back into greater infrastructure spending.)

While the effort to win votes by suggesting lack of success in gaining projects relative to other provinces encourages attacks on Ottawa, other factors encourage a degree of restraint, if not outright cooperation. Overplaying the "lack of success" card can increase the probability of the lack of future success if it sufficiently angers senior federal politicians. Ottawa has similarly mixed incentives: while it wishes to maximize its own credit *vis-à-vis* provincial governments for local projects by providing them only when it gets credit, it also wants to get projects actually built in regions to maximize votes within the federal electoral cycle.

The equilibrium outcome can best be described as a mixed form of competition and collaboration (Sproule-Jones 1993). Such a political equilibrium may, of course, result in underinvestment in

certain kinds of infrastructure, as well as the more usual pattern of overinvestment. The national highway system, for example, appears to suffer from serious underinvestment in both new infrastructure and maintenance.[10]

The underinvestment problem is exemplified by the Trans-Canada Highway, especially in western Canada (except in Alberta). The Trans-Canada, which is often billed as the longest national highway in the world, remains a two-lane road without a median in many stretches. There is evidence that significant numbers of truckers detour onto the US Interstate system, at significant opportunity cost, because of the Trans-Canada's condition. The highway's disadvantages may also be serious enough to divert considerable economic activity from western provinces to the western United States. While the federal government maintains that highways are a provincial responsibility, it collects the vast majority of fuel taxes, which go almost exclusively into general revenues rather than to highway development and maintenance.

The centrality of the bargaining between federal and provincial governments further increases the importance of the executive relative to the legislature, creating so-called executive federalism (Sproule-Jones 1993, 87–88). This tendency reduces the influence of individual MPs in the selection of infrastructure projects.

Summary: Current Infrastructure Incentives

The Canadian institutional framework involves bargaining among a relatively small group of politicians responsive to electoral interests. If they reach a consensus, fiscal policy can shift rapidly (Kelly and Wanna 1999). Such an hypothesis is at least consistent with the federal government's and most provinces' recent ability to constrain spending (Richards 1997, 69–82). Budget restraint does not, however, necessarily produce incentives to rank infrastructure projects according to either CBA criteria or the multigoal criteria sum-

10 We are forced to say *appears* in the absence of specific studies, but analogous US evidence certainly suggests that underinvestment is the case (United States 1983; Gramlich 1994).

marized in Table 1. Electoral incentives generally create a bias toward overinvestment in the ridings of important politicians and distort the selection of projects toward those offering immediate benefits or costs (especially where constituents see such expenditures as benefits). Decisionmakers also have incentives to favor projects whose costs are manifested as employment expenditures, which are perceived as benefits. More generally, infrastructure projects can easily get folded into grandiose industrial policy strategies in which projects are justified primarily on the basis of the jobs and multipliers that they generate, even though these rationales are largely specious.

The menu of project alternatives that ministries provide also sometimes reflects the bureaucratic interests of career civil servants. Guardianship-oriented bureaucrats, for example, often push infrastructure user fees that are well above the social marginal cost because they generate revenue.

Provincial-level decisions often do not take adequate account of the national-level effects of infrastructure projects.

A Prudential Perspective on Infrastructure Choice

How can the gap between normative criteria and positive behavior be closed? A prudential approach for improving the assessment of infrastructure projects must avoid two extremes: dogmatic adherence to a purely normative approach that ignores political realities and thus fails to alter behavior, and surrender to a purely political treatment that fails to alter behavior because it simply rationalizes what is already being done. Consequently, we seek an approach that moves infrastructure decisionmaking at least somewhat closer to the normative criteria outlined in Table 1.

Some Exemplary Models

We believe that what we seek involves changing the process of infrastructure assessment so that appropriate normative values

receive more attention. This approach is essentially the one taken in some US jurisdictions to force efficiency and cost considerations into regulatory decisionmaking. For example, eight states now have laws that require cost analysis, economic impact analysis, or cost-benefit analysis for new regulatory initiatives (Zerbe 1998). The law in Washington state goes furthest in requiring explicit cost-benefit analysis:

> The Washington law requires nine enumerated agencies to determine that the probable benefits of the rule are greater than its probable costs, taking into account both the qualitative and quantitative benefits and costs and the specific directives of the statute being implemented. (Ibid., 431.)

In 1995, the US House of Representatives passed a bill that would have required extensive use of cost-benefit analysis. Although the bill died in the Senate, there continue to be proposals to extend the mandatory use of cost-benefit analysis beyond the high-cost regulations (more than $100 million) already covered by executive order.

A Modest Proposal

Our specific proposal is as follows. In order for any federal department, province, or local government to receive any federal funds toward an infrastructure project, it would have to file for the public record with the Treasury Board and with the Public Accounts Committee of the House of Commons both a cost-benefit analysis and a multigoal analysis along the lines sketched in Table 1. The Treasury Board, one of the federal government's most important central agencies (Savoie 1999), would make these analyses available on the Internet along with a mechanism through which interested parties could attach comments to them as part of the public record. The US Congressional Budget Office already does something similar in publishing complete texts of its analyses on its website (www.cbo.gov; Weimer and Vining 1999, ch. 11); so do the Australian Productivity Commission (www.pc.gov.au/index.html) and the Joint Legislative Audit and Review Commission of the Virginia Gen-

eral Assembly (jlarc.state.va.us). The Crown Corporation Secretariat in British Columbia requires Crown corporations to produce what amount to multigoal analyses of major initiatives, although they are not made available for public scrutiny.

Ideally, provinces would require equivalent analyses to be filed by departments prior to the disbursement of provincial funds. As a preliminary first step, all provinces should ensure that they use a single, mandatory, well-publicized social discount rate across *all* agencies (in other words, not only those agencies involved in infrastructure projects). This requirement should include consistent dissemination and specification of whether the discount rate is real or nominal. Considerable evidence suggests that most provinces could not currently meet these standards.

Our proposal on cost-benefit and multigoal analysis has several purposes. The submission of the analyses to the Public Accounts Committee would help connect the process to Parliament as well as to cabinet. And since that committee is traditionally chaired by a member of the Opposition, it would provide an avenue for the monitoring of infrastructure analyses.

What would be the advantage of this arrangement?

- As the analysis would be subject to broad public scrutiny, it would require a project's sponsors at least to address the full range of relevant social values. Fear of embarrassment and loss of credibility would help to discourage the wildest claims of benefits. And interested academic experts would have a forum for critiquing analyses, further combating excessive claims.
- It would give added voice to two groups — environmentalists and big losers — that have incentives to challenge many proposed infrastructure projects. Environmentalists could monitor the claims made by project supporters about such impacts as loss of animal habitat and increased pollution. Big losers could highlight the costs that they would have to bear from the project. These groups might suggest modifications of the projects that would allow them to go forward but with smaller negative impacts.
- It would also provide a forum for a project's supporters to emphasize benefits that might otherwise be overlooked or

underestimated. For example, trucking firms might volunteer estimates of the savings they would accrue from road improvements, thus providing an additional source of information for estimating benefits.

- Over time, project sponsors could strengthen their analytic capability by observing the techniques employed by previous proposers. In the long run, this experience would contribute to better decisionmaking by providing standards of common practice for estimating the magnitudes of various types of costs and benefits. Indeed, by raising the sophistication of project assessments, this increase in capacity could potentially contribute to the design and selection of superior projects in the future.

Of course, this proposal is not a panacea. One major problem is that analytic capacity is scarce, so that the analyses initially posted might not provide very good implementations of the elements outlined in Table 1. As Gramlich points out in a recent review of US infrastructure,

> [w]ith all the pages written on infrastructure investment, one is struck by how little there is...[on]...particular rates of return — that is, on road maintenance in New York and Los Angeles, on new construction in San Francisco and Chicago and so forth. (1994, 1184.)

The same is true in Canada.

Analysis is scarce, probably for four related reasons. First, in most political arenas, any form of analysis has public-good characteristics — most of us value it but not enough to bear the often high costs of producing it. Most important, those who expect to benefit from projects are often most unwilling to support analyses that may show they would yield net social costs.

The second reason is the high cost *per se*. Major CBAs or multigoal analyses can be expected to range from a hundred thousand to a million dollars (United States 1987; Hopkins 1992). While this amount is only a small fraction of the cost of major infrastructure projects, it may be a deterrent in an era of budget cuts.

Third, relatively few people in government, especially at the provincial and local levels, have the requisite training and expertise to produce sophisticated analyses (Boardman, Vining, and Waters 1993). Purchasing analyses from consultants may get around these limitations, but only at a high dollar cost. Although these costs would limit, at least in the short run, the sophistication of analyses posted by a project's proposers, addressing the categories outlined in Table 1 should be possible, and these rudimentary analyses would likely be supplemented by interested parties. Over time, the collection of analyses would provide a resource for analysts at all levels of government, so the sophistication of assessments would gradually increase.

Fourth, at the moment relatively few costs are attached to a lack of analysis, poor analysis, or inaccurate prediction of future costs and benefits relating to existing projects. The best way to deal with these sins is to encourage *ex post* CBAs (Boardman, Mallery, and Vining 1994) as well as the *ex ante* CBAs and multigoal analyses that have been the major focus of this essay. Here, the federal and provincial auditors-general have taken some useful steps. With more expertise and more resources, they could do much more. Even the most thick-skinned politicians and civil servants, still in office or retired, do not like to be identified as the sponsors of projects that are shown to be losers.

Apart from the specific proposal we have described here, the federal and provincial governments can address directly all four of these problems by developing and funding analytic capacity at all levels of government.

Conclusion

We have set out plausible criteria for evaluating the social desirability of infrastructure projects. Although addressing these criteria in detail requires analytical capabilities often beyond those readily available in provincial and local governments, they nevertheless provide a framework for at least a cursory assessment of the desirability of infrastructure projects. Federal and provincial politics do not, however, routinely lead to the systematic application of such

criteria. The result is probably a tendency toward overinvestment in infrastructure generally but underinvestment in specific types of projects, such as highways.

We have suggested a mechanism — Internet publication of project analyses and comments by the Treasury Board — that would draw public and, therefore, political attention to appropriate criteria for assessing projects. Why would political leaders be willing to subject themselves to a mechanism that ultimately might limit their freedom of action? As political economists, we hesitate to argue that political leaders would see improving decisions about infrastructure investment as so important for Canada's future prosperity that they would be willing to bind their own hands by adopting a mechanism like the one we propose. At the same time, the mechanism is initially a very light binding that would likely tighten only gradually as the sophistication of routine analytical debate increased. Further, the current government may be willing to accept this light binding in return for a tighter binding of subsequent governments. Of course, given parliamentary sovereignty, this tightening would be only that of precedent and practice.

Political and bureaucratic leaders are likely to be more willing to accept such binding rules in a highly complex environment where everyone is uncertain about the distributional consequences of future infrastructure projects — that is, where all participants are behind a veil of ignorance. To take an example from the United States, Congress was willing to implement military base closings only when the rules were structured so that no members knew beforehand whether a base in their district was subject to closure (Weimer 1995, 8). Of course, for the reasons we have discussed, rank-and-file Canadian politicians have the right incentives to support an approach that allocates projects on merit, rather than the current method. Consequently, we think that a mechanism of the sort we propose may well be politically feasible if it can be introduced onto the public agenda.

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The Information Superhighway

Steven Globerman

The role of infrastructure in promoting national and regional economic growth has become an important focus of policy debate and academic research in recent years.[1] Increasingly, physical capital infrastructure is seen as underlying continued productivity improvements and higher real income levels. It is also coming to be viewed as attracting human capital to migrate to specific regions, thereby promoting a virtuous cycle of additional physical and human capital investment.

One very prominently discussed component of modern capital infrastructure is a region's computer communication networks, which, in recent years, are identified in the vernacular as the *Information Superhighway* or the *Information Highway*. This nomenclature tends to be applied to the various interconnected media capable of carrying out the switching and transmission of digital communication signals.

Commentators make extremely optimistic conjectures about the role that the Information Highway can play in stimulating improved productivity and faster real economic growth.[2] Such optimism is leading to calls for greater public sector participation both in promoting investment in the highway and in regulating economic activity and behavior on it.

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1 For an extensive review of the literature, see Gillen (this volume).

2 For an overview of these assessments, see United States (1994); Globerman (1996); and Canada (1997).

The purpose of this essay is to assess two broad questions: what economic consequences can Canadians reasonably anticipate from public and private sector investments in the technology and physical infrastructure of the Information Superhighway; and what roles, if any, should government play in promoting its development and in regulating its use?

The paper proceeds as follows. The opening section offers a relatively brief and nontechnical discussion of developments in the communications sector that underlie what many observers characterize as the emergence of the Information Superhighway. The following (and longest) section identifies and evaluates several hypotheses surrounding the likely economic consequences of the highway's continued growth and development. Next comes a section addressing the broad issue of whether government intervention is desirable in order to promote a socially desirable allocation of resources into the expansion and utilization of the new communications channel; the text includes identification and assessment of recent Canadian government policies directed at promoting the growth and development of the highway in Canada. Concluding comments end the essay.

Attributes of the Information Highway

Descriptions of the Information Highway are innumerable. Stentor provides perhaps the most straightforward and useful:

> It is a system of interconnected electronic networks providing universal access to basic and advanced communications and information services. It is a network of many networks, owned and operated by different service providers offering connections to a variety of services, applications and content sources. (1993, 6–7.)

The increasing ability of different media, such as wired and wireless telephony and cable, satellite, and computer networks, to share and exchange electronic traffic reflects a technological phenomenon referred to as *convergence*. In effect, communication networks are functioning more and more like computer networks in

the way they code, store, and forward information. In particular, treating electronic signals as digitized bits of information, rather than as analogue waves, allows alternative communication networks to offer an increasingly similar set of services, either as substitutes for or complements to each other.

The digitization of electronic signals and advances in the ability to compress and combine them into packets for purposes of transmission have facilitated the provision of new services on communications networks and reduced the direct costs of supplying traditional signals, such as voice telephony.[3] The associated new technologies allow communications networks (again more or less successfully and efficiently) to handle various types of traffic, including voice, data, enhanced text, graphics, sound, and video. They also allow networks to exchange different types of traffic (more or less successfully), so that modern communications systems are increasingly described as "networks of networks" that are evolving into "systems of systems" (Noam 1995).

One can view the Information Highway conceptually as the set of interconnected networks that provides the capacity for businesses and households to exchange digitized signals. Thus, it includes both the hardware and the software required to process, store, and forward those signals.

In practice, the highway is increasingly equated to the Internet and the associated World Wide Web. (For convenience I use the term *Internet* to encompass all on-line networks available through that ubiquitous public computer communication network.[4]) The dominant and most rapidly growing public network of networks is the Internet, and policy issues surrounding the new communications are increasingly debated in this context. Hence, the discussion of these communications is conducted, from this point on, within the context of Internet-related developments and issues.

3 Voice telephony still accounts for the largest share of total telecommunications traffic. See Globerman (1996).

4 Mackie-Mason and Varian (1997) define the Internet as a worldwide network of computer networks that use a common (TCP/IP) communications protocol.

The Internet

Perhaps the most notable feature of the Internet is its extremely rapid rate of growth. For example, by the beginning of 1996, the number of computers directly connected to this global network was some 9.5 million, a nearly 200 percent increase from 1995 (Solem 1998, 271). The number of users, of course, is much larger, since a substantial percentage of interconnected computers are, in turn, connected to other computers in local or wide-area networks. The number of Internet users is extremely difficult to estimate, but Solem (1998) offers an estimate for 1996 of nearly 50 million. A more recent estimate puts users at around 360 million as of July 2000.[5] The growth in the number of web sites provides a similar picture. For example, one on-line survey estimated the presence of around 1 million sites on the World Wide Web in 1997. A similar survey carried out in April 1999 reported over 5 million sites.[6]

Identifying the type of information being carried over the Internet is very difficult to do with any precision. One comprehensive survey of 1997 Internet usage reports the responses of a sample of users (Americans age 18 and older). Approximately 58 percent indicated sending or receiving e-mail was an important use of the Internet. Around 43 percent reported that reading about current events was an important use. Some 36 percent said that "getting product information" was an important Internet application. Another 15 percent cited "meeting people or participating in chat lines and bulletin boards." And approximately 14 percent said they considered product ordering an important use of the Internet.[7]

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5 Approximately one-half of the estimated users are in North America. See Internet website: www.nua.ie/surveys/how_many_online/index.html (accessed October 2000).

6 See Internet website: www.nua.ie/surveys/index.cgi?f=vstart_id=905354851 &rel=true.

7 Ibid. Since respondents could cite any number of possible uses of the Internet as being important, the total percentage response can exceed 100 percent.

Electronic Commerce

An indication of the increasing importance of the Internet as a communication medium for commercial transactions is the growth of electronic commerce. The most encompassing definition of *electronic commerce* includes any form of business activity conducted on the Internet, including electronic mail; however, for purposes of evaluating the commercial significance of the Internet, commentators generally reserve the term to describe commercial transactions among businesses (B-to-B commerce) and between businesses and household consumers (B-to-C commerce). Distinctions are often blurred between commercial transactions consummated on the Internet and those for which it is used to advertise and promote products and services that are purchased using more conventional channels.[8]

Systematically collected data on electronic commerce activity are unavailable. What one finds instead (and primarily for the United States) are *ad hoc* observations and estimates about the use of the Internet for commercial transactions, often for specific applications. Summarizing relatively disparate estimates of the volume of electronic commerce, Table 1 reports Internet shopping dollar values (B-to-C transactions) in various product categories for 1997, along with projections for 2000. Table 2 reports more recent estimates for all electronic commerce activity on a global basis. The wide range of estimates underscores the need for caution in drawing conclusions about the quantitative importance of electronic commerce activity.

In summary, the focus of policy attention is increasingly the growth and use of the Internet, particularly as it has come to be viewed as an especially efficient medium for carrying out public and private sector transactions. Hence, the perceived economic

8 A recent study concludes that approximately 60 percent of the purchases identified were consummated using conventional market channels, such as mail order catalogues, even though the availability of the goods may have been identified through the Internet. The study is discussed in "Internet commerce booms," *The Bellingham Herald*, November 22, 1998, E2.

Table 1: ***Estimates of Internet Shopping***

	1997	2000[a]
	(millions of US dollars)	
PC hardware and software	863	2,901
Travel	654	4,741
Entertainment	298	1,921
Books and music	156	761
Gifts, flowers, and greetings	149	591
Apparel and fashion	92	361
Food and beverages	90	354
Jewellery	38	107
Sporting goods	20	63
Consumer electronics	19	93
Other	65	197
Total	2,444	12,090

a Projections.

Source: "The Virtual Mall Gets Real." *Business Week*. January 26, 1998, 90–91.

benefits of the Internet underlie many of the arguments for public policy initiatives to promote its growth and use.

Potential Economic Consequences

Most observers foresee the primary broad economic consequence of the Internet as improved productivity growth accompanied by faster real economic growth. However, many identify a wider range of benefits that would amount to nothing less than an economic transformation comparable to the Industrial Revolution. The scale and scope of the hypothesized consequences are illustrated by the following quotations:

> The enabling effects of the information highway will be felt in all industry sectors and all regions of Canada. It will stimulate research and development in leading-edge technologies; it will facilitate the diffusion of innovative technologies and information-based services; it will strengthen the competitiveness of large and

Table 2: ***Consultant Estimates of Worldwide E-Commerce***

	1999	2003	Average annual growth
	(billions of US dollars)		(%)
E-markets	98	1,224	89
IDC	111	1,317	85
Active Media	95	1,324	93
Forrester Low[a]	70	1,800	125
Forrester High[a]	170	3,200	108
Boston Consulting Group	1,000	4,600	46

a Includes Internet-based electronic data interchange.

Source: Cappel 2000, 7.

> small Canadian businesses; and it will produce cost-effective access to high quality health care, educational and social services. (Canada 1994.)
>
> When companies are linked the way telephones are linked, we shall create entirely new computer-mediated markets, new ways of doing business, new social patterns, new opportunities and new forms and definitions of work. (Denton 1994.)

The Internet and Market Failure

While the quotations above do not explicitly address a role for public policy that would leverage more effectively and efficiently the Internet's potential benefits, they implicitly identify features of it that might supply economic justifications for government intervention.[9]

One is the important role that new communications technologies could continue to play in improving the efficiency of services traditionally supplied or paid for by government. Such improve-

9 For an explicit discussion of the role for public policy in the future development of electronic commerce, see Mann (2000).

ments in efficiency would presumably justify government's increased funding of the hardware infrastructure and software platforms used by its agencies and departments to supply public services. One cannot argue against a greater utilization of the Internet by governments if doing so would improve the efficiency and effectiveness of the public sector. (Presumably, government agencies and departments would pay competitive prices to access the requisite Internet capacity.)

Much less obvious is the logic underlying the call for policies that would increase government spending as a means of generating commercial demand for new forms of communications infrastructure and services. The notion here is that government should deliberately play the role of a leading-edge consumer and stimulate, by example, utilization of the new technology by other sectors of the economy. The obvious concern about this policy approach is the danger that government would indirectly fund new technologies that had no realistic prospects of commercial viability. At the same time, increased government expenditures and their associated financing would create deadweight costs for society. Such costs are associated with changes in economic behavior stimulated by higher taxes and government transfers.[10] The potential for such costs implies that government funding of the Internet, for whatever reasons, must provide substantial anticipated social benefits. (A later section outlines the Internet's potential productivity benefits.)

A second important characteristic, highlighted by the quotations, that raises *a priori* concerns about the failure of markets to develop and utilize the Internet efficiently is the relative newness of the technology and its use to supply services. Indeed, whole new commercial markets may be created as a result of the Internet.

Overall, anyone thinking about the role of public policy in promoting the Internet must carefully consider whether the evidence reveals market failure, which is the usual economic justification for government intervention.

10 It is not possible to summarize the extensive literature on the deadweight costs of public finance. The interested reader might consult Boardman et al. (1996, ch. 3).

Externalities

Perhaps the most obvious potential cause of market failure in the context of the Internet is the well-known propensity for innovators to incompletely appropriate returns to innovation. Specifically, one can find evidence that a substantial portion of the commercial benefits of new technology goes to consumers and rival producers who did not directly share in the costs and risks of developing the underlying innovation.[11] To the extent that incomplete appropriability results in less innovative activity than is socially desirable, a potential argument exists for government intervention. Indeed, a host of public policies, ranging from intellectual property protection to subsidies of private sector research and development (R&D), are theoretically founded in a concern that, absent government interventions, the private commercial rewards for risk taking may be inadequate to promote sufficient innovation.

Another set of potential externalities associated with the development of the Internet is intrinsic to new communications networks. Traditional notions of communications network externalities relate to access and usage. *Access externalities* refers to the increased value that a larger network has to its existing members, since they have the option to call or receive calls from an increased number of sources. *Usage externalities* refers to the net benefit received by called parties who do not pay directly for calls received; as a network grows in size, its existing members can expect to receive more of these surplus-creating calls.

The implication of these externalities is that networks may fail to grow to their optimal size or they may grow more slowly than is socially desirable because incumbents do not compensate new subscribers for the value the latter convey to incumbents upon joining the network. Some people think the remedy is increased govern-

11 There is a vast empirical literature on this issue. For one overview paper, see Levin et al. (1987). To be sure, the Internet may financially harm many third parties. For example, the Internet may make pornography and hate messages more readily accessible, which a broad segment of society would see as social costs. The potential existence of such costs argues against government subsidies to promote the growth and development of the Internet.

ment subsidies, either to suppliers of network services or to their potential subscribers.

For us, the relevant issues here are:

- Is the Internet characterized by substantial externalities?
- If so, can participants economically internalize many or most of the potential third-party effects?

The literature dealing with conventional telecommunications networks concludes that they have few access or usage externalities at Canada's existing subscriber penetration rates (Fuss and Waverman 1995). That is, subscription to the telephone system is virtually universal, so the opportunities additional subscriptions create for incumbent subscribers are insignificant at the margin. However, subscription to the Internet, though growing rapidly, is still much more limited. While this observation, taken by itself, suggests the existence of large demand-side externalities associated with additional growth of the Internet, another mitigates against the inference that government intervention is appropriate or even necessary. Specifically, subscription to the Internet in the United States is growing so quickly that (at current rates) usage levels in 2001 will approach those for conventional telephone services (Cawley 1997).

Perhaps a more relevant consideration dampening this externalities argument for increased government intervention is that Internet participants may be able to internalize most of the spillover effects of usage.[12] For example, many organizational intranets are being constructed on top of the backbone (public) network, so many individuals join the Internet as part of a group in which access and usage externalities can be fairly readily identified and internalized by members of the relevant communities of interest. For example, the intranet manager of a corporation or a trade association may handle such externalities by making access to the Internet available to all members as part of extending access to the group's intranet. In other cases, managers of the intranet can offer

12 The following arguments are discussed in more detail in Globerman (1998b).

strong and direct financial incentives for individuals and groups to join the backbone network.

Direct and indirect incentives provided by suppliers of Internet services can encourage access and usage, even among members of the population who are not members of an organizational intranet. This approach may be particularly relevant given the increasing trend for marketers to tie conventional product offerings to Internet services. An example is the National Basketball Association, which provides fans with electronic access to their favorite players and other services, usually with no direct cost to the user. Another example is Vidéotron and six consortium partners, which plan to offer a range of infomedia services delivered over cable. The set-top boxes required to access the services will be provided free of charge.

Policy-related discussions of the Internet also describe potential externalities on the supply side of the market. One set relates to standards. To the extent that participants in a new communications network harmonize their hardware and software standards, they mitigate risks of interoperability problems that would reduce the overall value of the network to participants. Since other participants can, at relatively low cost, potentially appropriate the effort and expense that any one-network participant puts into the standards-setting process, they may be tempted to free ride on the efforts and expenditures of others. This potential for free riding could, in turn, discourage network participants from making substantial investments in establishing and implementing effective standards.

The proper role of government in helping to establish and implement standards for public communications networks is a contentious issue. In particular, there is a risk that allowing bureaucrats and regulators to play a larger role in the standards-setting process invites the potential for increased political rent seeking by noncompetitive suppliers.[13] This concern is particularly relevant in Canada, where appeals to nationalism usually strike a resonant chord with domestic politicians and regulators. Thus, one can see a clear danger of government decisionmakers' tilting the standards-setting process in favor of domestic suppliers, even if doing so implied

13 The example of the promotion of Minitel in France is a case in point.

sacrifices of efficiency and effectiveness. The scope for nationalistic rent seeking is limited, however, by the incentives of large telecommunications equipment suppliers, such as Nortel, and large corporate users of the Internet to ensure compatibility between US and Canadian standards. Indeed, the *de facto* dominance of US participants in the standards-setting process renders the Canadian government's potential role quite limited.

A second broad source of supply-side externalities arises from the imperfect appropriability of technology discussed earlier. Internet suppliers of new services, such as multimedia web sites, convey information to potential users about what types of services might grow in future demand.[14] While no one can legally duplicate the precise details of a web site, features of a commercially successful site can be copied — in theory discouraging innovation in the supply of new Internet services.

Overall, innovation spillovers are a well-documented source of market failure and offer a reasonably compelling *a priori* justification for increased government involvement in the emergence and growth of the Internet. One must, however, keep in mind the caution that the historical record of government subsidies for high technology speaks more to the effective lobbying of special interests than to the public interest served (Faulhaber 1993, 5).

Public Goods

Assertions about the potentially dramatic and "regime-shifting" technology changes associated with the Internet suggest that such changes have certain attributes of public goods. Public goods are, in various degrees, nonrivalrous in consumption, nonexcludable in use, or both.[15] A good is *nonrivalrous* in consumption when more

14 Faulhaber (1993) points out that the use of the Internet by certain groups of consumers can identify the value of the Internet to groups of nonusers, thereby creating knowledge spillovers (or externalities) among consumers. This point is connected with my earlier discussion of a demonstration effect associated with government use of the Internet.

15 This definition is taken from Weimer and Vining (1989, 40–41).

than one person can derive benefits from consuming it without reducing the benefits realized by others. A classic example is national defense; its provision to additional people does not affect the amount of the "product" available to others within the nation. A good is *non-excludable* when it is physically or legally impractical for those who own it to keep nonpayers from using it. National defense is again a reasonable example; once it is extended to some citizens, it is, by definition, available to all.

If a good is nonrivalrous in consumption, price is an economically inefficient rationing device. To put the point differently, it is efficient to use multipart pricing in which usage prices are zero and total costs are recaptured by flat fees calibrated to be no greater than the consumption benefits consumers realize. Furthermore, to the extent that consumers differ in their valuations of the benefits of specific nonrivalrous goods, charging different consumers different flat-rate fees may be efficient. Such pricing is, of course, inconsistent with the traditional competitive equilibrium in which price equals marginal cost, and the inefficiency of competitive pricing underlies government regulation of suppliers as public utilities.[16] Hence, the potential issue of whether the Internet should be treated as a public utility arises to the extent that the marginal cost of using it is close to zero at existing and foreseeable usage rates.

While the Internet culture is, to date, largely associated with nonpriced direct usage, the incremental costs for users are generally not zero, given that many popular web sites are subject to congestion and even the basic distribution infrastructure is subject to peak-load bottlenecks. In short, it is likely that charging explicit usage-based prices for the Internet will become an efficient pricing scheme over time. To this extent, the Internet does not qualify as a public good.

Moreover, for most relevant uses, access to the Internet can be restricted; that is, exclusion is quite feasible. To be sure, excluding access to certain broad benefits may be impossible in practice. For example, to the extent that the Internet makes certain product mar-

16 For a discussion of the economics of pricing "public utility type" goods, see Crew and Kleindorfer (1990).

kets more competitive, the resulting benefits are realized by those who continue to use conventional channels of distribution to acquire goods and services, as well as by those using electronic channels.[17] As a result, many who might pay to use the latter to shop for cheaper goods may continue to use conventional channels of distribution and avoid the need to pay for Internet access and usage. If this phenomenon proves important, public subsidies might be justified for initiatives to develop electronic commercial markets.[18]

The obvious availability of private financing for companies offering Internet-related services belies the need for additional government funding, perhaps except for specialized uses that are not commercially attractive. On the other hand, the limited ability of B-to-C Internet companies to earn profits, at least to date, may ultimately restrict the availability of venture capital to this sector. At the same time, the limited profitability of such businesses raises a question about whether the benefits to consumers of shopping on the Internet are significantly greater than those realized through conventional shopping channels. Certainly, no one has offered compelling and consistent evidence, at least to date, that lower prices on the Internet are leading to a substantial substitution away from conventional bricks-and-mortar businesses.

Currently, one sees more optimism about the future growth of B-to-B electronic commerce. A growing number of consortia are establishing web sites through which customers and suppliers can buy and sell specialized products, such as auto parts, specialty metals, and so forth. Again, it is unclear whether and to what extent such web sites will displace or extinguish conventional distribution channels for the products involved. In any case, the proliferation of such sites without any government funding belies the

17 For a discussion of the industrial organizational implications of electronic commerce, see Globerman (1998a).

18 A nuanced version of this argument might propose that relatively large network economies are associated with electronic commerce and that public subsidies are needed if electronic markets are to reach a critical mass, as long as "defection" to conventional product markets is encouraged by loading all costs of electronic commerce onto current users of the Internet.

notion that B-to-B commerce can be characterized as a public good for policy purposes.

In short, while traditional notions of externalities supply a plausible potential rationale for government involvement in promoting the development of the Internet, viewing it as a public good does not seem warranted.

Imperfect Information

Another possible justification for government intervention in a market is that participants (buyers or sellers) lack complete, accurate information on which to base decisions.

The diffusion path of a new good or service is conditioned by the perceived benefits and costs (including associated risks) that potential adopters associate with it. To the extent that they overestimate the costs and risks or underestimate the benefits, the resulting rate of adoption is likely to be socially inefficient. Government initiatives to improve the quantity and quality of information in the marketplace might, therefore, be economically appropriate, particularly to the extent that free-rider and related problems discourage private suppliers of Internet-related services from providing credible information of appropriate quality.

One obvious consideration arising in the context of this imperfect-information argument for government policy is whether bureaucrats are in a position to improve the quantity and quality of the market information available. For example, one can plausibly argue that, in a rapidly changing economic and technological environment, government officials are likely to be substantially less well informed than private sector investors and managers about the economic opportunities in the relevant sector. Another argument is that it is far from clear that imperfect information necessarily leads to unduly pessimistic forecasts of economic opportunities in a sector. Indeed, pundits' continued references to "irrational exuberance" in the stock market, especially in relation to the so-called dot-com stocks, bespeak excessive optimism, rather than undue pessimism, about economic returns related to the Internet. In this context, government initiatives should presumably

be directed at discouraging the herding instinct in capital markets that might lead to overinvestment in Internet-related hardware and software.

I am aware of no evidence that addresses the issue of whether private investors are systematically overestimating or underestimating private sector returns to Internet-related investments. Yet, it again seems that the policy issue is whether the existence of significant externalities will create a divergence between the expected private and social rates of return to such investments. That is, the relevant issue is whether or not externalities are contributing to the prospect of substantial market failure.

Market Power

A final market-failure argument for government intervention in the marketplace is the presence of *market power*, a condition that producers enjoy when they can profitably increase and maintain prices above those required to cover all costs and provide a normal return to invested capital. Such noncompetitive prices can lead to a misallocation of resources. Specifically, sectors characterized by market power may produce at a less than socially efficient output rate. Also, since market power means that inefficient producers are not necessarily driven from the market, it can also lead to costs being higher than they need to be in order to produce any given amount of output.

The existence of market power is usually associated with a relatively high degree of industrial concentration (a few producers account for a large share of industry output). However, when entry into a sector is relatively easy, the prices charged are still likely to be competitive, even if concentration is relatively high.

Sectors that are relatively easy for new sellers to enter are called contestable. (Specifically, a contestable market is one in which the sunk — or unrecoverable — costs of entry and exit are relatively low compared with the potential profits associated with entry.)

Despite differences of opinion, most observers argue that the provision of Internet-related services is not a contestable market. In particular, since local access through the wired telephone and cable

networks is most users' link to the Internet, the relatively concentrated ownership of local network distribution facilities, along with the relatively high sunk costs of de novo entry, militates against a conclusion that market power is an irrelevant consideration in accessing the Internet.[19] Indeed, the local Bell operating companies in the United States are, by and large, still prohibited from offering long-distance services because the country's regulatory authorities do not believe that local telephone access and service are competitively supplied. Since local network distribution services are even more highly concentrated in Canada, one can reasonably argue that the promotion of competition is and should be an integral part of any government strategy to promote the benefits of Internet-related technology.

Equity Considerations

Some commentators seek government support of Internet services because of concerns about equality, not market failure. Perhaps the main such concern is worry about a "digital divide." Tapscott (1994), among others, raises the prospect of technological "haves," who will be technically competent to utilize new computer-communications technology in their production and consumption activities, while the "have-nots" will not. As a consequence, the former will enjoy higher real income levels associated with improved efficiency as workers and as consumers, both absolutely and relatively to the latter.

If proficiency in exploiting Internet-related technologies is largely determined by an individual's socioeconomic status — in particular, their attained educational level — the diffusion of the relevant activities and services may exacerbate existing inequalities in the distribution of income, since real income levels and attained education levels are strongly and positively correlated.

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19 The US government's opposition to the recently proposed (and subsequently abandoned) merger between Worldcom and Sprint was predicated on a concern that it would result in undue concentration of ownership of long-distance fiber-optic transmission capacity used to carry Internet traffic.

In fact, some evidence suggests that educational performance in primary school may significantly enhance an individual's ability to adapt to technological change, including new techniques of production (Globerman 1985). An implication of this evidence is that the benefits of the Internet need not be highly concentrated among upper-income socioeconomic groups *if* the primary educational system does an adequate job in equipping all members of society to leverage the benefits of new technology. This point is underscored by the claim made by Jim Barksdale, former CEO of Netscape and co-chair of the Internet Policy Institute: the major barrier to widespread use of the Internet is illiteracy ("If U can read this...," *Wall Street Journal*, October 27, 2000, W17). More support comes from recent evidence that nearly half of all users of the Internet in the United States have only high school degrees and around 40 percent make only US$15,000 per year (ibid.).

A more direct potential equity concern is that lower-income individuals and families may not be able to afford home computers and cable set-top converters, as well as other complementary inputs necessary for connecting to and using the Internet. This impediment could, in turn, restrict lower-income families from accessing the income-enhancing benefits of the Internet.[20] If the potential problem is deemed significant, policymakers might need to consider whether and how universal access to the Internet could be guaranteed. In fact, however, cost does not appear to be a substantial hindrance to wider use of the Internet. For example, a recent survey found that only around 9 percent of current nonusers of the Internet say that the reason they do not have access is that the Internet is too expensive (ibid.).

In summary, if a real danger of a digital divide exists, it appears to be primarily related to illiteracy. This situation seems to call for public policies ensuring that graduates of Canada's primary education systems possess basic literacy and numeracy skills that can be augmented, if needed, by workplace training or higher educa-

20 Income enhancement should be thought of in the broadest sense — including, for example, considerations such as the ability to participate more effectively (if desired) in community affairs and to more easily correspond with friends, family, and so forth.

tion. But this policy imperative arguably exists even in the absence of the Internet.

Government Policies

The inference to be drawn from the preceding section is the applicability to the Internet of the "traditional" concern about a social return to investments in physical infrastructure that is higher than the private return. The existence of productivity spillovers or externalities constitutes one plausible rationale for government intervention. A second is the existence of market power in the telecommunications sector, especially in the provision of local network distribution services.

Externalities Related to the Internet

A substantial literature focuses on the returns to public infrastructure investments and on comparisons of social and private rates of return to investments in physical capital.[21] Also, several studies evaluate the returns to investments in telecommunications infrastructure (see, for example, Roller and Waverman 1996; Madden and Savage 1998). Very few researchers question the assertion that rates of return have been relatively high for both private and public sector investments in telecommunications infrastructure. Indeed, it seems self-evident that levels of economic development in Canada and elsewhere would be substantially lower if the telecommunications infrastructure looked as it did in the 1920s, rather than as it is currently configured. Yet researchers are also forced to acknowledge that econometric complexities and limited data prevent reliable estimation of private and social rates of return to telecommunications infrastructure investments (Roller and Waverman 1996). Neither is much known about possible interactions between private and public telecommunications infrastructure investing. For example, are they net complements or net substitutes?

21 A detailed critical review of the literature is provided by Gillen (elsewhere in this volume).

Reliable evidence on the social and private rates of return to investments in telecommunications infrastructure dedicated to the provision of Internet-related services is essentially nonexistent. Indeed, one cannot, in practice, isolate the component of the communications infrastructure supplying Internet-related services, since much of it is also used to provide "conventional" communication services. Nevertheless, some indirect evidence suggests a plausible case that the Internet is associated with substantial productivity externalities. For example, Majumdar (1997) provides econometric evidence that the diffusion of digital technology in the local operating sector of the US telephone industry over the 1991–93 period stimulated operating efficiency improvements and facilitated the introduction of new communications services.[22] Such developments were likely also associated with improvements in the economic welfare of telephone subscribers.[23]

We also have evidence, albeit largely anecdotal, of significant cost savings associated with electronic commerce carried out on the Internet. These savings, which are primarily associated with B-to-B commerce, vary widely depending on the nature of the commercial transaction. For example, the overall cost saving associated with buying inputs on-line ranges from 2 to 40 percent depending on the specific input. As another example, for products that can be delivered through the Internet, one can anticipate costs on the order of 50 to 90 percent less than those for delivery through conventional channels.[24]

It should be noted that these estimates are, however, quite crude, and they are not net savings for society. Rather, they are the

22 A substantial portion of the roll-out of digital technology is arguably associated with the provision of computer-communications services.

23 On the other hand, Fuss (1994) estimates that the annual rate of growth in total factor productivity for Bell Canada averaged close to 3.0 percent over the 1980s, slightly lower than the averages of between 3.3 and 3.5 percent for the 1960s and 1970s. Even assuming that unit costs decline at a rate commensurate to this increase in total factor productivity, the associated cost savings to customers are likely to be modest, since communications costs average less than 2 percent of total business costs.

24 A review of some estimates of the productivity impacts of electronic commerce is provided in Globerman (2000).

purely private cost savings associated with electronic commerce. Nevertheless, major innovations generally have social rates of return that exceed the private cost savings to users (Kamien and Schwartz 1986). Hence, if the anecdotal evidence on cost savings from B-to-B electronic commerce is approximately reliable, it suggests a relatively high rate of return, social as well as private, to infrastructure investments in the Internet.[25] It also suggests that government support for the faster and more extensive utilization of the Internet is economically desirable.

Policy Initiatives

Obviously, the plausible existence of productivity externalities does not identify appropriate policy initiatives. In particular, public policies should operate at the margin — that is, they should significantly expand investment in the desired way and not merely subsidize investments that would have been made otherwise.

Arguably, for most households and small and medium-sized businesses, the major barrier to accessing the full benefits of the Internet is the paired copper telephone wires that connect most small subscribers to the local network. The narrow bandwidth of the connection currently limits the transmission of moving video images, as well as the speed at which data can be transmitted between the subscriber's computer and the Internet. Technological developments to solve this "last mile" problem are ongoing, but the associated costs look to be quite high. Indeed, the current costs may be higher than is justifiable, given the demand of households and businesses for broadband Internet services. In this regard, gov-

25 The Organisation for Economic Co-operation and Development (OECD) offers an economy-wide estimate of the total cost savings associated with the adoption of electronic commerce by member countries (OECD 2000). Specifically, it estimates that total economy-wide costs would be reduced by about a half to two-thirds of a percentage point, savings that it suggests would be a proxy for total factor productivity gains. Since those annual gains averaged only around 0.8 percent across the economies of Group-of-Seven countries over the 1979–97 period, the OECD's estimated consequences of electronic commerce are relatively substantial.

ernment funding to improve the technical performance of the Internet might well contribute to its faster and more extensive adoption.

Indeed, to date, the primary direct focus of public policy has been funding the Internet's infrastructure, both hardware and software. The main instrument of this effort has been the Canadian Network for the Advancement of Research, Industry and Education (CANARIE), which provides financial and technical support for Canada's Internet backbone, increasing the country's Internet capacity and providing links to its US counterpart (Canada 1997).[26] CANARIE's original high-speed experimental test network connected universities and other public institutions. More recent efforts have aimed at connecting municipalities and local communities to the network.

According to its 1999/2000 annual report, CANARIE continues to define its mission as extending the connectivity of the network, both within Canada and between Canada and other countries, as well as developing new applications for the Internet. In broad terms, this focus is consistent with a presumed private sector underinvestment in advanced hardware and software to extend the network geographically and to facilitate new uses of the Internet.[27]

Direct and indirect financial subsidies to promote the Internet are also extended through grants and tax expenditures for domestic R&D, much of which is done by Bell Canada, Nortel, and other Canadian communications companies and equipment manufacturers and much of which is focused on Internet technologies. Through Technology Partnerships Canada, the federal government makes repayable investments in various information technology

26 CANARIE is a nonprofit organization consisting of dues-paying members from the public and private sector. The original network (CA*net) linking universities and research organizations was dissolved in 1998, and Bell Canada and other regional telephone companies took on the task of operating the Canadian Internet backbone. The current version of the network is known as CA*net 3.

27 It is obviously beyond the scope of this essay to assess whether specific priorities of CANARIE are economically appropriate — or whether the organization is spending the "right" amount of money on its activities.

projects that include the development and use of electronic commerce and Internet software. Ottawa also indirectly subsidizes domestic telecommunications carriers by not charging for spectrum and territorial rights-of-way, increasing shares of which are dedicated to Internet traffic.

Government laboratories also carry out research and development in areas directly and indirectly related to the Internet. For example, Industry Canada's Communications Research Centre has increasingly become involved with the interoperability and interconnectivity of wired and wireless services (Canada 1997). In addition, the center's Broadband Applications and Demonstration Laboratory serves as a hub for various experimental and test networks, focusing on, among other things, the capacity, efficiency, and accessibility of the Internet and other wireless networks. Recent federal government budgets have included funding for the Canada Infrastructure Program, which involves matching funds from provincial and municipal governments; although the program does not focus specifically on the Internet, telecommunications infrastructure projects are eligible for funding and have been emphasized in the program's announcements.

Obviously, other factors influence the adoption and use of the Internet. Examples include concerns about violations of privacy and insecurities about the integrity of on-line payment systems. These issues are related to the broader problem of technical and regulatory standards for the Internet. The federal government works with industry in developing such standards, although they have largely been implemented to date through voluntary agreements among industry participants. As the Internet grows and especially as it becomes more international, the role of government in assisting an increasingly diverse set of private sector participants to negotiate and implement open and competitive standards is likely to grow. Nevertheless, as a small country, Canada's influence at the international standards-setting level is likely to remain small. Assuring that incumbent domestic firms do not restrict competitive entry by imposing costly standards that discriminate, particularly against would-be entrants, may prove a more important focus for government activity in the future.

Competition Policy

Full consideration of Canada's policies to promote competition in the communications sector is well beyond the scope of this essay. However, several features of the country's competition policy, as applied to the communications sector, arguably contribute either to reduced competition (and contestability) or to a potentially inefficient form of competition.

One such feature is restrictions on the foreign ownership of communications companies.[28] Limitations on foreign ownership can conceptually limit the entry of new competitors to the extent that multinational communications companies, such as Deutsche Telekom and British Telecom, prefer to maintain managerial control of their foreign operations. Foreign ownership restrictions can also discourage domestic capital investment, as well as reduce the efficiency with which the sector uses physical capital and technology. For example, to the extent that the transfer of new Internet technology into Canada from outside is facilitated by the unrestricted operations of multinational telecommunications companies, such restrictions may slow the rate at which technology, both embodied (in capital equipment) and disembodied, is adopted and implemented within the country.

Whether or not the potential costs of foreign ownership restrictions are small or large is almost irrelevant, since few, if any, significant social benefits can be associated with those limitations.[29] Rather, foreign ownership restrictions can be best understood as an aspect of the Canadian government's broad policy to redistribute income from the consumers of communications services to the suppliers of specific inputs, particularly those classified as cultural

28 Under Canada's commitments as a signatory to the World Trade Organization Agreement on Basic Telecommunications, foreigners are restricted to no more than 20.0 percent direct ownership of a facilities-based supplier and 46.7 percent indirect ownership. Up to 100 percent foreign ownership is, however, allowed for mobile carriers, as well as fixed satellites and submarine cables. (See Globerman and Hagen 1998.)

29 For a critical evaluation of the major reasons for foreign ownership restrictions, see Globerman (1995).

inputs.[30] This policy is coming to be recognized as unsustainable, as more and more "content" is distributed over the Internet.

The panoply of direct and indirect Canadian-content regulations also influences competition in the communications sector. Such regulations influence the ability of carriers to obtain broadcast licenses and to compete through product differentiation. To the extent that requirements to carry Canadian content limited entry into the provision of Internet services, such requirements would likely discourage the entry of content suppliers, especially those who would enter primarily by supplying lower-cost imported programming. Yet if direct and indirect domestic content requirements were not applied to the Internet, conventional broadcasters would be burdened with higher costs and limitations on their ability to differentiate content through foreign programming. Inefficiencies could result, particularly if Internet broadcasters proved less efficient than conventional broadcasters in the absence of a discriminatory regulatory regime.

This caution should not be interpreted as support for existing or even revised Canadian-content regulations in broadcasting.[31] On the contrary, it is a suggestion that the preferred alternative to extending inefficient regulations to the Internet is to eliminate those regulations as they apply to conventional broadcasters.

A similar concern about asymmetric regulation arises with respect to telephony. As voice telephony on the Internet emerges as a significant use of the public network, conventional suppliers of telephone service will raise the issue of whether Internet suppliers of long-distance and premium service options (such as call waiting and call forwarding) are making a "fair" contribution to local-access subsidies. Since conventional telephone carriers are expected to make such contributions, exempting Internet telephone companies from them would seem unfair. Any such exemption could also produce inefficiencies by imposing a cost penalty on conventional telephone companies that could lead callers to bypass these more efficient firms in favor of Internet carriers.

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30 For an extensive discussion of this policy focus, see Stanbury (1998).

31 For detailed critiques of Canadian government policies affecting broadcasting content, see Schultz (1996) and Stanbury (1998).

Once again, acknowledging problems associated with asymmetric regulation is not an endorsement of existing subsidies to local access. Rather, a more efficient policy would be to eliminate cross-subsidies in the telephone rate structure and, if necessary, to extend direct subsidies to low-income families whose access to basic telephone service was threatened by substantially higher prices for local access.

Policy Conclusions

To the extent that one views the Internet as infrastructure investment, it raises the same primary policy question as does investment in other forms of infrastructure — namely, do the expected social rates of return exceed the expected private rates of return? Very little reliable empirical evidence on the issue is available. Nevertheless, one can make a plausible theoretical case that significant productivity spillovers are associated with the Internet, and that they constitute an argument for public policies to encourage investments in relevant hardware and software innovations.

Existing government policies focused on the direct and indirect funding of such innovations seem, therefore, to be justifiable and well directed, at least in principle. The available evidence does not permit persuasive argument about whether government is doing too much or too little subsidization. There does, however, seem reason for concern that enthusiasm about the Internet's economic benefits and promotion of the need for more active government promotion are excessive. Such optimism could well lead to inefficiently large direct and indirect public sector investments in the Internet. Given the current limited state of knowledge about the magnitude of its spillover benefits, combined with a wealth of empirical evidence on the relatively large size of deadweight economic costs associated with taxation and subsidy programs, policy officials arguably should err on the side of caution in substantially expanding government promotion of Internet capacity.

There are stronger conceptual and empirical grounds for arguing that existing regulations and cultural policies affecting the communications sector are inefficient. While there seems to be an emerging consensus among policymakers that the Internet is inher-

ently difficult to regulate, exempting the Internet from regulations that apply to other communications media is undesirable. Rather, content and foreign ownership restrictions that currently apply to the broadcasting sector should be eliminated. In addition, efficient competition in the provision of new communications services requires the elimination of policy-induced cross-subsidies in the pricing of communication services. To the extent that access to public communications networks for low-income subscribers is threatened by competitive pricing, the appropriate policy response is direct subsidization of those subscribers.

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Evaluating a Large-Scale Infrastructure Project:

A High-Speed Railway along the Quebec City to Windsor Corridor

Fernand Martin

For many years, people in government and business circles have expressed interest in linking the main cities along the Quebec City to Windsor corridor by means of a high-speed railway (HSR). Such systems have been put in place in a number of countries, including Japan and France. Political interest in this venture has waxed and waned over the years.

In 1992, the governments of Canada, Ontario, and Quebec jointly undertook a major feasibility study of such a project, looking at the engineering problems associated with use of HSR technology in Canada's harsh climate, the determination of alternate routes, estimates of probable ridership, and a cost-benefit analysis. The final report (Canada, Ontario, and Quebec 1995) concluded that an HSR project is technically feasible and that certain routes would be economically viable inasmuch as they would generate a positive net present value. This essay reviews the results of the HSR cost-benefit analysis, the final version of which was published in 1995 (Transurb 1995). That report is interesting in that it provides an example of the application of cost-benefit analysis to a real-world proposal.

The High-Speed Rail Project

The most ambitious HSR variant is 1,200 kilometers in length and would link six cities (Quebec City, Montreal, Ottawa, Kingston,

Toronto, and Windsor), as well as the major airports of Montreal and Toronto (see Figure 1). The total population of the metropolitan areas of these six cities is nearly 11 million (according to the 1996 census). More than 9 million of this total reside in communities along the central, Montreal–Toronto portion of the corridor, which is a much shorter 600 kilometers in length.

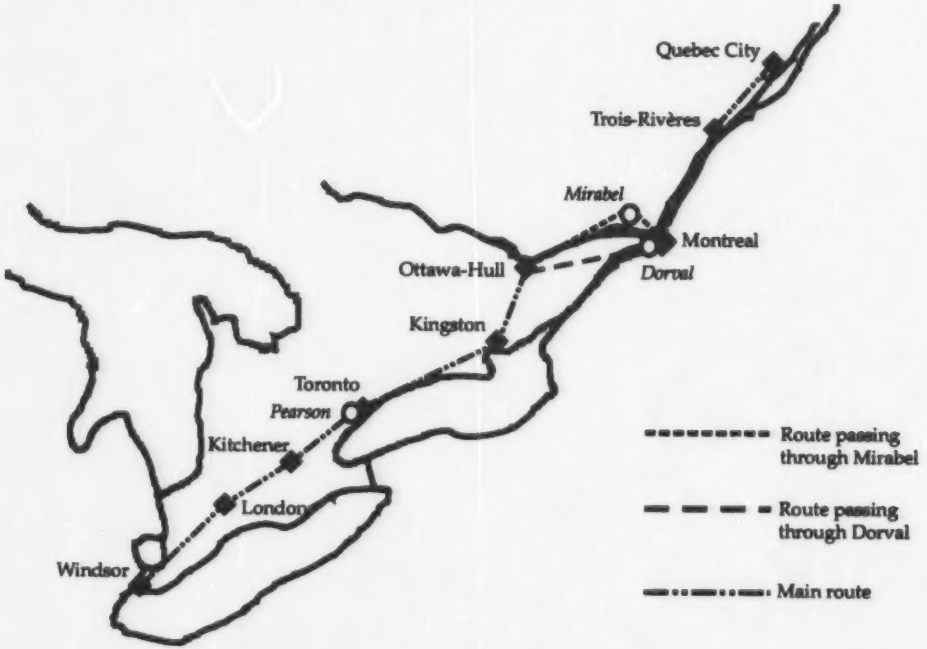
This population distribution along the corridor prompted the committee to consider cost-benefit analyses for several project variants. Some extended along the entire 1,200 kilometers; others were restricted to the shorter central portion.

The choice of technology provided another dimension for differentiating project variants. Lynx technology (the GEC-Alsthom, which is used by the French *trains à grande vitesse* — TGV) allows trains to reach 320 km/h, but it requires a special railbed. Another technology, Sprintor (a Swiss-Swedish technology also called the X-2000 ABB train), is capable of only 200 km/h, but its body-tilting trains have the advantage of being able to run on suitably improved existing railbeds.

Focusing on the two dimensions of route length and technology, the technical committee asked a consultant to undertake detailed computations for HSR variants involving subsets of the six cities, two lengths (Quebec City–Windsor, Montreal–Toronto), and two technologies (Lynx and Sprintor). To be precise, the six variants were:

1. Quebec City–Windsor, using Lynx technology, covering six cities, and passing through Mirabel airport;
2. Quebec City–Windsor, using Sprintor technology, covering six cities, and passing through Dorval airport;
3. Quebec City–Windsor, using Lynx technology, covering six cities, and passing through Dorval airport;
4. Montreal–Toronto, using Lynx technology, covering four cities, and passing through Mirabel airport;
5. Montreal–Toronto, using Sprintor technology, covering four cities, and passing through Dorval airport; and
6. Montreal–Toronto, using Lynx technology, covering four cities, and passing through Dorval airport.

Figure 1: ***HSR Representative Routes, Quebec–Ontario***



Source: Canada, Ontario, and Quebec 1995, 12.

A nonstop Lynx-based train could complete the Montreal–Toronto journey in 2 hours, 18 minutes, compared with an estimated 4 hours, 30 minutes for conventional rail and 1 hour, 15 minutes for air (see Table 1).

The values assigned to economic variables were based on engineering data that, through optimization routines, determined the number of trains, the frequency of service, pollution, route alignment, and so on.[1]

The most difficult estimating exercise was forecasting ridership of an HSR. In 1992, intercity passengers generated a total of 109 million person-trips along the Windsor-Quebec City corridor: 99.0 million by automobile, 4.1 million by air, 2.9 million by conventional rail, and 2.6 million by bus. Three consulting firms made forecasts; the final estimate used was an average derived from two of their results.

The forecasting entailed use of a multinomial logit model. The work began with an estimate of the total direct demand for travel between each pair of cities for each available travel mode (air, conventional rail, bus, automobile). Then, for each city pair, the consultants estimated the proportion of each existing mode that would be diverted to an HSR. The estimates of diversion were based on a logit model that incorporated as explanatory variables travel time, the generalized cost (cash plus value of the time), the frequency of service, and a constant to capture unobserved characteristics of the HSR relative to other modes.

In summary, the forecasters estimated that a Sprintor-based HSR along the entire corridor would generate 10 million riders; the faster Lynx-based HSR, 12 million.

They concluded that approximately one in five HSR riders would be induced to travel by the availability of the HSR; the other four would be diverted from some other mode. Of total HSR riders, 40 percent would be diverted from automobiles 18 percent from airlines, 15 percent from conventional rail, and 8 percent from buses. The largest impact on existing modes would be on airlines,

1 These routines, largely borrowed from French experience, are described in Levinson et al. (1997).

Table 1: ***Typical Travel Times and Cost Inputs, Montreal–Toronto, 2005***

Input Variable	Local Air	(VIA) Rail	Bus	Auto	HSR[a]
Time *(hours and minutes)*					
Access, egress, and terminal	1:48	1:33	1:29	—	1:30
Line-haul (in-vehicle)[b]	1:15	4:30	6:38	6:20	2:18[c]
Departures per day	45	12	18	N/A	36
Costs (business) *($)*					
Access and egress	36.40	19.10	15.80	—	18.60
Fare	175.00	85.00	48.40	—	132.60
Operating costs *(per person)*	—	—	—	22.00	—
Total costs (business) *($)*	211.40	104.10	64.20	22.00	151.20
Costs (nonbusiness) *($)*					
Access and egress	15.00	7.40	4.90	—	7.00
Fare	119.00	64.00	46.60	—	98.20
Operating costs *(per person)*	—	—	—	22.00	—
Total costs (nonbusiness) *($)*	134.00	71.40	51.50	22.00	105.20

[a] HSR service at 300 km/h via Mirabel airport, along the Quebec City–Windsor corridor.

[b] Travel time and fares shown are weighted averages developed in the composite forecasts.

[c] HSR travel times vary by scenarios and by number of stops.

Source: Canada, Ontario, Quebec 1995, 28

which were estimated to lose 44 percent of their projected corridor ridership in 2005.

The Rationale for Cost-Benefit Analysis

The technical committee opted for a cost-benefit analysis as the appropriate technique to evaluate infrastructure projects.

In such analysis, one considers all costs and benefits that flow to members of society. Conceptually, a *benefit* derived from an infrastructure project is any positive impact for which people would be willing to pay; by extension, a *cost* is an impact that obliges members of society to forgo benefits. One considers only incremental changes in benefits and costs relative to what would obtain in the

project's absence. These are the actual impacts arising from the infrastructure project being evaluated; sunk costs (those that have already been incurred) are not relevant.

Once all costs and benefits over the project's lifetime have been evaluated in money terms, they can be calculated for a particular point in time by means of discounting. The present value of benefits minus the present value of costs equals the net present value. A project is justifiable in a cost-benefit analysis if its net present value is positive. That means, among other things, that the winners could compensate the losers if forced to do so, and a surplus would remain.

Table 2 sets out the summary results for the six HSR variants described above. Notice that five of the six have positive net present values for Canada. The distribution of costs and benefits between Quebec and Ontario varies according to the option.

Roughly speaking, the technical committee's working hypothesis was that government would finance the fixed HSR infrastructure (for example, stations and railbed) and the private sector the rolling stock and operations. Because the project was to be financed by a mix of private and public funds, the discount rate used was a weighted average of the cost of public and private funds.[2] In projects with a long life, choice of discount rate can be crucial in determining whether net present value is positive or negative. At the Canada-wide level of analysis, for example, at 8 percent (the base discount rate used in these analyses), all variants of the project except variant 2 have a positive net present value. However, only one variant still has a positive net present value when the discount rate rises to 10 percent.[3]

2 The economic cost of private funds was set at 7 percent and that of public funds at 10 percent. The latter rate represented the weighted sum of three sources — the pre-tax return on private projects squeezed out by public investment, the after-tax cost of increases in Canadians' private savings, and the cost of imported finance — all in constant dollars.

3 For more on the subject of discounting in the conduct of cost-benefit analysis, see Moore, Boardman, and Greenberg elsewhere in this volume. Were the cost-benefit analysis of the HSR project to use a lower discount rate, as these authors suggest, the calculated net present values would be higher.

Table 2: ***Summary Statistics for Variants of the HSR Project***

	Variant					
	1	**2**	**3**	**4**	**5**	**6**
			Net Present Value *(millions of 1993 dollars)*			
Canada	683.5	−319.7	1,186.8	687.9	82.7	1,284.8
Ontario	171.4	−531.7	260.9	283.0	−212.5	430.1
Quebec	−166.2	−222.1	122.6	−53.0	6.9	245.1
			Benefit:Cost Ratio *(ratio of net present value of benefits and of costs)*			
Canada	1.10	0.95	1.17	1.18	1.03	1.34
Ontario	1.10	0.71	1.15	1.28	0.81	1.43
Quebec	0.81	0.73	1.16	0.88	1.02	1.85

Note: See the text for specification of the routes and technologies for each variant. The cost-benefit analysis estimated total benefits and costs accruing to all Canadians and those accruing to residents of the two provinces primarily affected by the project. The Ontario and Quebec results reported do not add to the Canada results because they come from different models that vary in the way they define costs, benefits, and transfer payments.

Sources: Transurb 1995, annex B; Canada, Ontario, and Quebec 1995, 70.

Social Benefits and Costs

The social benefits in the case of, say, building a road between towns A and B, are determined by the total amount that drivers would be willing to pay to use that road, relative to other available transport modes. This amount corresponds to the road taxes they would have to pay plus their *consumer surplus* (the amount by which an individual's total willingness to pay for an item exceeds what he has to pay to buy it). To that amount, cost-benefit analysis adds positive externalities; for example, an increase in public safety if the new road will be safer than the existing route between towns A and B.

On the other hand, the social costs of building and maintaining the new road consist primarily of the forgone benefits of something else that could have been built and maintained with the diverted construction and maintenance crews. Use of the land for the road is an additional cost because of the forgone benefit of other uses. To

that amount must also be added negative externalities, such as damage to surrounding land and properties. Net *social benefits* is the difference between social benefits and social costs.

The practitioners of cost-benefit analysis defend its use with a variety of arguments. Probably the most compelling is that, since decisions about building roads and other public projects are essentially political, this kind of analysis imposes a desirable discipline on what might otherwise be an exercise in interest group politics. If government decides to spend a given amount on infrastructure projects, it is better that it build roads, bridges, and so on for which people would be prepared to pay, rather than undertake projects for which citizens have no willingness to pay. Viewed this way, cost-benefit analysis is an attempt to incorporate efficiency into government decisionmaking in domains, such as infrastructure, where private competitive markets cannot readily operate.

Impact Studies

Infrastructure projects cannot be assessed on the basis of so-called impact studies. Such studies start from the idea that the goal is job creation and that public infrastructure investment creates new jobs — both directly among those employed in the projects and indirectly through the chain of suppliers and as those newly employed spend their incomes. That is why impact studies invariably conclude that infrastructure investment should be undertaken. Such studies rely, however, on the false assumptions that resources would be drawn from a pool of permanently unemployed people and capital and that the economic cost of these factors is nil because no other way exists to put them to work or use. If that is not the case — and in general it is not — then it is important to assess the opportunity cost of labor and capital diverted to the project from other activities.

Distribution of Net Social Benefits

In any analysis of infrastructure projects, one must distinguish conceptually between, on the one hand, benefits and costs determined by willingness to pay and, on the other hand, distributional issues

concerning who would incur the costs and who would realize the benefits. Indeed, cost-benefit analysis implies the acceptance of the compensation principle: a project with a positive net present value is one for which the winners could compensate the losers.

The distribution problem appears because compensation may not be paid. For example, all taxpayers in a province may bear the entire cost of building a road between towns A and B, while the beneficiaries of the road are solely the residents of the two towns, who pay only inasmuch as they are taxpayers.

Of course, one could explicitly incorporate distributional concerns into the analysis of infrastructure projects by attributing differing weights to the costs and benefits accruing to particular groups, based either on the region in which they reside or on their income. But this approach is impractical. So cost-benefit analysts typically consider a dollar of benefit received or cost incurred by a rich man equal to a dollar of benefit received or cost incurred by a poor man; the benefits accruing to those in towns A and B are no more nor no less valuable than benefits in towns C and D. Thus, they urge that distributional considerations be addressed by other means, such as redistributive social programs and the income tax system.

That said, the making of public infrastructure decisions is often constrained by more than the sign of a project's net present value. With large infrastructure projects — and an HSR along the Quebec City–Windsor corridor would be a *very* large project — policymakers must assess and debate distributional concerns. The HSR project would require government subsidy. For variant 6, for example, the analysts calculated net monetary revenues of $3.1 billion,[4] an amount $0.7 billion less than total costs. Yet the project has a positive net value because of a large consumer surplus ($1.1 billion). Proponents of projects that imply a large redistribution to Canadians who will use the service from taxpayers who live elsewhere or will not use it for other reasons should seek approval in a political arena. Democratically elected political representatives should have

4 They derived this figure from a revenue optimization exercise undertaken by the ridership forecasters. The exercise involved market segmentation by class of customer (for example, business versus nonbusiness).

a say, especially in a federal country, where large projects simultaneously affect many utility functions, one for each province and one for the country as a whole.

Classification of Costs and Benefits

The HSR cost-benefit analysis found that, of the six variants studied, variant 6 had the largest net present value. The major categories of benefits and costs are presented below. A somewhat more detailed list is set out in Table 3.

Costs

The major costs associated with an HSR would be those relating to investment and operations.

Investment Costs. An HSR would incur substantial investment costs, mostly in upgrading the railbed, rolling stock, and so on to the standards of either Lynx or Sprintor. In variant 6, these costs are nearly $3.5 billion, eight times higher than the present value of net operating costs. Netted against these costs are the reduction in investments in conventional rolling stock.

Operating Costs. These are less substantial than investment costs, but still sizable. Recall that all costs and benefits are incremental relative to the status quo. In the analysis, the gross operating costs of the HSR — about $1.1 billion (= $1.0 billion + $100 million) — become $400 million once the $700 million benefit from canceling conventional trains is accounted for. VIA Rail would cease conventional rail activities in the HSR corridor. (In the preferred variant 6, conventional trains would no longer operate between Montreal and Ottawa or Toronto; they would, however, continue to run between Montreal and Quebec City, and between Toronto and Windsor.)

The estimated offset from reduced investment in conventional trains is not large (about $100 million), but the reduced operating

Table 3: ***Costs and Benefits for Canada, HSR Variant 6***

	Present Value	Proportion	Undiscounted Value
	($ millions)	*(%)*	*($ millions)*
Costs			
Investment costs			
Rolling stock and infrastructure	3,543.9	90.4	6,650.9
Small parcels equipment	64.5	1.7	188.1
Present rolling stock (conventional train)	–131.2	–3.4	–321.3
Subtotal	*3,387.1*	*88.7*	*6,517.6*
Operating costs			
HSR	989.5	25.9	4,502.1
Small parcels	121.1	3.2	580.0
Conventional train	–709.1	–18.6	–3,137.9
Subtotal	*401.6*	*10.5*	*1,944.2*
Negative externalities			
Foreign exchange premium (on imports)	21.5	0.6	41.0
Use of agricultural land	8.5	0.2	29.2
Total costs	*3,818.7*	*100.0*	*8,531.9*
Benefits			
Operating revenues			
HSR	3,404.3	66.7	16,429.6
Small parcels	238.7	4.7	1,163.6
Concessions	2.5	0.0	11.1
Conventional train	–504.2	–9.9	–2,265.5
Subtotal	*3,141.2*	*6.0*	*15,338.8*
Consumers' surplus HSR	1,164.1	22.8	5,717.4
Residual value	626.7	12.3	6,810.6
Gain through shadow-pricing labor:			
Direct labor	41.1	0.8	123.1
Indirect labor	21.0	–0.4	–145.2
From conventional train	–7.0	–0.1	–31.3
Subtotal	*13.1*	*0.3*	*–53.4*
Positive externalities			
Reduction in pollution	4.5	0.1	26.3
Public safety	153.8	3.0	707.8
Subtotal	*158.3*	*3.1*	*734.0*
Total benefits	*5,103.4*	*100.0*	*28,547.4*

Note: The rounding of figures introduces small discrepancies.

Summary results: Net present value, $1,284.8; benefit:cost ratio, 1.34; discount rate, 8.0%; internal rate of return, 10.9%

Source: Martin 1997, 172.

costs are important since VIA Rail employs a relatively large number of workers.[5]

Negative Externalitites. Since all costs must be accounted for from the social point of view, whether the project is supported by users or not, the costs of involuntary uses of resources must be incorporated into the computations. In the case of the HSR, these costs consist of the use of agricultural land and the foreign exchange premium on imports generated by the project. They are relatively unimportant (see Table 3).

Benefits

The major benefits of an HSR service are discussed below.

Willingness to Pay for HSR Service

Willingness to pay for an HSR was, as already noted, the most problematic component of the evaluation, due to the uncertainty in estimating ridership. The central concept underlying cost-benefit analysis is to measure benefits in terms of what people would be willing and able to pay if they were required to do so, and to measure costs in terms of benefits forgone due to the diversion of resources away from other activities in which they could be employed. Thus, any such analysis of HSR projects must evaluate the willingness of passengers to pay for the improved rail service.

Anyone considering travel between two cities must expect to derive a benefit from the trip. The maximum cost that the traveler would be willing to incur for the trip is the appropriate measure for the benefit derived. In choosing to travel, passengers incur two

5 Note that the analysts did not consider the negative impact on the demand and profits of other modes of transportation as a social cost of an HSR. The reason is that, in the case of constant returns to scale and competition (the case of the Canadian scheduled airlines), the properties of the Marshallian demand curve are such that the loss of consumer surplus in a substitute such as the airlines is immaterial (Zerbe and Dively 1994, 145).

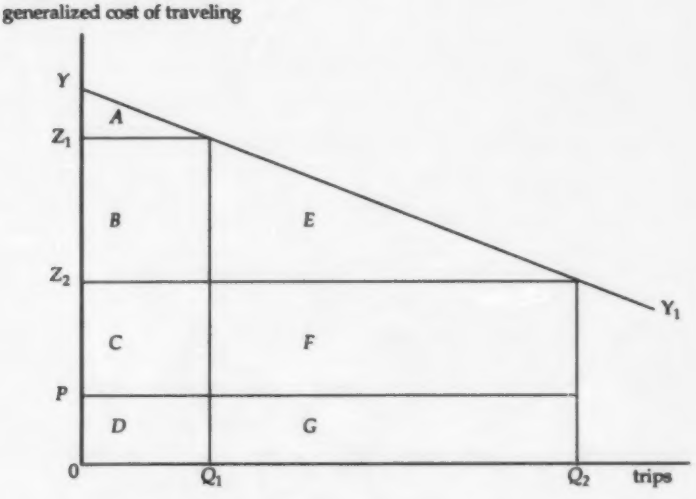
separate categories of cost. The first is the cash costs of a ticket and other ancillary expenses, such as parking fees, taxi fare to reach the station, and so on. The second is the implicit cost incurred by spending time traveling rather than doing something else. The expenditure of money is obviously a cost: the funds could be devoted to some other purpose. Travel time also a cost, because people are willing to pay to reduce it (for example, they are willing to pay an air fare that is much higher than a train fare for the same trip). The sum of both costs is called the *generalized cost of traveling*.

People engage in voluntary market transactions only if they perceive a net benefit from doing so. In a market for travel, consider first the marginal traveler, the one for whom the trip's generalized cost — cash plus cost of travel time (the latter measured in money terms) — just equals her maximum willingness to pay. She is indifferent between traveling or staying home. All passengers who value the trip more than she does unambiguously want to travel under the prevailing cost conditions. Each of these intramarginal passengers realizes a benefit that exceeds the cost incurred. The monetary measure of this net benefit is consumer surplus.

The lower the costs people incur in making a trip between, say, Montreal and Toronto, the more potential travelers will perceive themselves realizing a net benefit from the trip. The function YY_1 in Figure 2 illustrates the hypothetical demand for train travel between the two cities as a function of the costs incurred by travelers — under the assumption that other relevant variables (such as incomes and the costs of alternate travel modes) remain constant.

The implication is not that the costs travelers incur equal the costs of providing the rail service — obviously, travelers cannot avoid the travel time costs they incur. However, the aggregate cash costs travelers incur may or may not equal the costs the rail corporation incurs to provide its service. If the cash cost travelers incur is higher, then a producer surplus accrues to those producing the service. If the cash cost is lower, then production costs are being redistributed to some other group (or partly to the producers in some other way). Potentially, those producing the service earn less than their opportunity costs (that is, less than what those who provide labor and finance could earn in some other activity). Or, as takes place here, taxpayers assume a portion of the costs.

Figure 2: ***Demand for Rail Travel***



Consider the demand for travel under two alternative technologies: the present slow train (designated by subscript 1 in the following) and a potential fast train (designated by subscript 2). The number of trips presently being made with the slow train is Q_1. The "Q_1st" passenger — the indifferent passenger — realizes no consumer surplus. The generalized cost he would incur to make the trip, Z_1, equals the benefit he would derive from it. All other passengers would realize at least some consumer surplus. With a ticket price P, the aggregate revenue earned by the railway company from Q_1 passengers is represented by the rectangular area D. Then the implicit travel time cost per trip is $(Z_1 - P)$. The aggregate travel time costs these passengers incur is represented by $(B + C)$. Under reasonable assumptions, the aggregate consumer surplus among passengers making the trip is represented by the triangle A. Hence, the gross benefit among those traveling (their total willingness to pay) is the monetary value represented in areas A through D.

Now consider the demand for rail travel with a fast train linking the two cities. Suppose the generalized cost of the travel is Z_2.

The indifferent passenger becomes the "Q_2nd." For simplicity, assume the ticket price remains unchanged (which does not imply that the cost of producing the trip remains unchanged). In this case, the railway company's aggregate revenue is $(D + G)$. The major advantage to the consumer of any HSR project is reduced travel time cost, from $(Z_1 - P)$ to $(Z_2 - P)$ per trip. Aggregate travel time costs for all passengers are now $(C + F)$. As illustrated, consumer surplus has significantly increased, from A to $(A + B + E)$. The gross benefit of, or total willingness to pay for, a fast train is the monetary value represented in areas A through G.

In assessing the benefit derived from an HSR project, a cost-benefit analysis evaluates the increase in benefits — that is, the change in aggregate willingness to pay due to the project. Graphically, this requires evaluation of the monetary value of $E + F + G$. This change can, in turn, be disaggregated, as in Table 4, into the change in cash payments to the railway, the change in implicit time costs incurred, and the change in consumer surplus.[6]

Producer Surplus in Salaries

To the extent those working for the HSR corporation would earn salaries that exceed what they could expect to earn elsewhere, they would be receiving a rent. As well, the HSR might lead to increased employment in other sectors, and those working there would also

6 This discussion illustrates consumer choices when the demand is a function of the time cost stemming exclusively from the value of the marginal product of business labor. But in other situations — say, the competition between the HSR and the airlines — such analysis may be inadequate. A multinomial logit model is usually used to establish travel demand. In that case, it is possible that the cash and time costs of using HSR, which are based on the marginal product of business labor, would be smaller than the cash and time costs of air travel and still have travelers traveling by air. This is so because the multinomial logit approach incorporates not only cash and time costs but also amenities or unobserved characteristics of the different travel modes. This approach usually provides no winner-takes-all. Since an important proportion of the HSR passengers would come from the airlines, Figure 2 illustrates only a small extent of the aggregate increase in consumer surplus. (For a more complete discussion, see Martin 1997, appendix A.)

Table 4: ***Change in Gross Benefits from High-Speed Rail Relative to Conventional Rail***

	Conventional Rail	High-Speed Rail	Change
Cash payment to railway	D	D + G	G
Time cost to passengers	B + C	C + F	F – B
Consumer surplus	A	A + B + E	B + E
Total	A through D	A through G	E + F + G

Note: For a graphic explanation of the letters, see Figure 2.

collect a rent. The cost-benefit evaluation determined that such a benefit would exist, although as a relatively minor item. Another way to state this idea is that the investment and operating costs — that is, the forgone benefit associated with diverting labor and capital to the HSR — are being overestimated by the amount of this benefit in salaries, which is shown as "gain through shadow-pricing labor" in Table 3.

Residual Value of Assets

One expects large infrastructure projects, while long lasting, to come to the end of their useful lives someday. The HSR cost-benefit evaluation assumed a life from 1995 to 2025. The choice of a 30-year planning horizon for detailed projections was a compromise between using a longer period to cover the potentially useful lifetime of all assets and, on the other hand, using a shorter one because probable future changes in technology and the costs of resources render projections increasingly dubious as the horizon lengthens.

The analysts then undertook a separate assessment of the residual value (calculated as a present value in 1995) of the useful remaining life of assets in place after 2025.

Positive Externalities

The category of positive externalities comprises benefits accruing to people not directly participating in the provision or use of the

HSR. The analysts quantified two kinds of external benefits. The first was a reduction in air pollution, a benefit to society that would arise because the pollutants generated per passenger-kilometer of rail travel are much lower than those for either air or road travel.

The second was a reduction in travel-related accidents. Rail is an inherently safe mode of transport, and the expected accidents per passenger-kilometer of rail travel are much lower than the comparable statistics for other modes. Moreover, since accidents are an increasing function of road congestion, the diversion of automotive passengers to rail would benefit not only the diverted passengers but also those who continued to use roads, which, being less congested, would pose a lower risk of accident.[7]

Results

The net benefits of large projects often depend crucially on the assumptions made about the appropriate values of a few key variables. *Ex ante*, it may be hard to identify which variables matter in this regard. But one can use simulations to ascertain the relative importance of many assumptions.

The HSR analysts undertook two types of simulations: some involving change to one variable at a time, and others involving simultaneous changes to a collection of mutually interacting variables. In the first type of simulations, different parameters were chosen for the following variables:

- the impact of the HSR on the other modes of travel;
- the discount rate (to 7 percent and to 10 percent);
- the consumer surplus (to either zero or a high level);

7 Evaluating the relative safety of alternate travel modes entails placing a monetary value on human lives, inevitably a controversial calculation. Analysts use two main approaches: the willingness to pay for lowering the risk assumed (for example, willingness to accept a lower salary for a safer job), and the value of human capital (for example, the forgone net earnings due to loss of life or injury). These approaches yield varying estimates of the value of life. Given this, some economists shy away from such computations, but others show some interest (see, for example, Jones-Lee 1989; and Lanoie 1995).

- the residual value;
- ridership (increasing or decreasing it by 10); and
- investment costs (increasing or decreasing it by 20 percent).

Variant 6 kept a positive net present value in each scenario, whether the values of the variables were low or high. For two variants, net present values became negative when the negative impact on other modes was charged to the HSR project. All variants except variant 6 were negative at a 10 percent discount rate. The same was true when the consumer surplus was not counted and when investment costs were increased by 20 percent. A loss of 10 percent of revenues eliminated only two variants. Changes in the residual value played no role.

Finally, when a collection of variables was used in their low values (the discount rate was set to 10 percent, revenues were lowered by 10 percent, and investment costs were higher by 20 percent), no variant had a positive net present value.

Conclusion

No action has been taken since the report was made public, nor have the official reasons for the inaction been made public. Yet one can presume that, since variant 6 would increase welfare largely because of the presence of a consumer surplus, people might have had second thoughts about the project since this outcome would entail Canada-wide taxation. Since only two provinces would gain from such a project, interregional transfers of income would be necessary, which may be politically unacceptable.

Another probable reason for the inaction is that variant 6, although advantageous to Quebec in general, does not include Quebec City on its route, which is a drawback in the eyes of the Quebec government.

Thus, in a federal country, projects that are efficient at the national level may be rejected on interregional equity grounds, engendering a suboptimal transportation infrastructure.

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Issues in Public Infrastructure in Canada

Aidan R. Vining and
John Richards, editors

Assessing an economy's infrastructure is like examining one's health: it is of concern only when something goes wrong. Residents of Ontario and Quebec, for example, did not bother themselves much with their electric power grid until the 1998 ice storm flattened it.

This collection of essays seeks to interest policymakers in infrastructure policy, writ large, without the spur of a crisis, since certain general purpose assets — physical facilities such as roads, railroads, seaports, and airports, and intangible human capital — are necessary for sustained economic development.

Infrastructure policy is important, but complex and hard to get right. Infrastructure investments in different sectors of the economy require different things. Some need public money, some need effective public management, and others need less public management and greater reliance on market mechanisms.

Over the past generation, it has become normal for politicians, journalists, and the general public to pose questions about appropriate monetary policy. A more mature discussion similarly needs to take place with respect to infrastructure policy. The public should expect governments to report the results of cost-benefit analysis before launching major projects. Journalists and politicians should understand the logic of these techniques sufficiently to pose meaningful questions about net present values, discount rates, and other such concepts.

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